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BULLETIN No. 983

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

FOREST PRODUCTS LABORATORY, MADISON, WISCONSIN
IN COOPERATION WITH THE UNIVERSITY OF WISCONSIN

Washington, D. C. PROFESSIONAL PAPER. April 6, 1922

THE MANUFACTURE OF ETHYL ALCOHOL FROM WOOD WASTE

By

F. W. KRESSMANN
Formerly Chemist in Forest Products

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PREFATORY NOTE.

This report is based primarily on experiments conducted by the author, Mr. F. W. Kressmann, at the Forest Products Laboratory, prior to December, 1916. The information thus obtained has been supplemented by the results obtained in succeeding years by Mr. Kressmann while in private employment as manager successively of the Standard Lessee Corporation and the International Alcohol Corporation and as director of the development department of the latter corporation. Acknowledgments are due these companies for their consent to the utilization of information obtained by Mr. Kressmann in connection with his work for them and to Mr. Kressmann himself for his assistance in the completion of the investigation and report.

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UNITED STATES DEPARTMENT OF AGRICULTURE

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THE MANUFACTURE OF ETHYL ALCOHOL FROM WOOD WASTE.[1]

By F. W. KRESSMANN, *formerly chemist in Forest Products.*[1]

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SOURCES OF ETHYL ALCOHOL AND COMPARATIVE COSTS OF PRODUCTION.

The production of fermentable sugars and ethyl alcohol from cellulosic materials, such as straw, linen, cotton, peat, wood, and in fact, all plant fibers, has engaged the attention of chemists and technologists for nearly a century. It is only within the last two decades, however, that serious attempts have been made to utilize wood waste for this purpose. The principal sources of fermentable sugars from which alcohol is at present derived are the hydrolytic products of starch and the sugars obtained from fruits and such sugar-factory residues as molasses.

Corn yields about 2.4 gallons of 188-proof spirit a bushel; and, although the price of corn and other grains used varies with the

[1] The author acknowledges with pleasure his indebtedness to Messrs. Homer Cloukey and H. N. Calderwood, of the Forest Products Laboratory, whose aid in making the hundreds of analyses necessary to the research was invaluable. Acknowledgment is made also to Drs. S. F. Acree and E. C. Sherrard for helpful criticism and review. For help rendered by men from outside the Forest Service, the author acknowledges his obligations to Messrs. Boyt and Groves, of Georgetown, S. C., to Dr. R. C. Gravenburg, distillery superintendent, at Fullerton, La., and to Dr. T. B. Wagner, of New York. Many others have assisted in the production of this work, and to all of them the author is grateful.

season and from year to year, before the war the average cost of the materials for making grain alcohol, fuel excluded, was about 27½ cents a 188-proof gallon. Manufacturing costs, including coal, interest, repairs, depreciation, taxes, labor, etc., range from 10 to 17 cents a gallon of 188-proof alcohol, depending upon the location and efficiency of the plant.

One gallon of molasses yields from 0.45 to 0.48 of a gallon of 188-proof spirit. The price of molasses before the war averaged from 5 to 7.5 cents a gallon, and, therefore, the approximate cost of raw material in a gallon of molasses spirit was from 10 to 15 cents. The cost of production of molasses spirit is slightly less than that of grain spirit, but in either case the cost of raw material is comparatively high.

One ton of dry sawdust or other wood waste (or its equivalent on an air-dry or green basis) will yield from 12 to 20 gallons of 188-proof spirit. The disposal of this waste in the vicinity of a sawmill or other large woodworking plant is specifically an item of loss, because most sawmills produce waste in excess of their own power requirements. Sometimes the waste is not worth more than 30 to 50 cents a ton, and this makes the cost of raw material in a gallon of ethyl alcohol from sawdust about 2 cents. This includes also the fuel charge, for the residue after conversion and extraction is available for fuel, whereas in grain distilleries about 7 tons of coal and in molasses distilleries about 4 tons are required in producing 1,000 gallons of 188-proof spirit.

If the manufacturing cost of producing ethyl alcohol from wood can be reduced to the same figure or nearly the same as that for making it from grain or molasses, there will be a large margin in favor of producing the alcohol from wood waste. Of course, with a yield of 12 to 20 gallons from a ton of wood and 80 gallons from a ton of corn, the amount of material handled in certain parts of the plant producing alcohol from wood will be four or five times as great as in a grain distillery of equal producing capacity, and this will require a larger-sized plant and an increased operating cost.

In recent years the production of ethyl alcohol from sawdust has received a great deal of attention, and a large amount of money has been spent in the technical development of the process. A number of plants have been built in this country, but only two have been considered commercial successes.

Because of the importance to the lumber industry of the problem of waste disposal, and because this process is practically the only one applicable to the disposal of wood waste, the Forest Service has investigated the different processes and, so far as possible, the plants that have been built, in order to learn the causes of former failures and to aid in the commercial development and success of the processes.

AMOUNT OF WOOD WASTE AVAILABLE.

The amount of wood waste produced by converting a tree or a sawlog into lumber is, of course, variable and depends upon the diameter of the tree, the quality of the timber, and the efficiency and equipment of the sawmill. The following tabulation shows that more than half of the cubic contents of the tree is wasted:

	Per cent.		Per cent.
Entire tree	100	Slabs	8
Stump	2	Edgings	8
Top	18	Shavings	4
Sawdust	12		62
Bark	10		

This includes limbs, top, and stump—the parts of the tree left in the woods—in addition to the waste at the mill or factory. The mill waste, particularly the part available without extra transportation charges, is of great interest in connection with the manufacture of ethyl alcohol.

The annual cut of lumber in the United States for the five or six years preceding the World War was approximately 40,000,000,000 feet board measure.[2] The mill waste from this cut has been estimated by Margolin [3] as follows:

	Per cent.
Sawlog	100
Bark	13
Sawdust	13.5
Edgings and trimmings	8.7
Slabs	8.7
Careless manufacturing and accidents	3.5
Loss in cutting to standard widths and lengths	1.7
Total waste	49.1
Lumber	50.9

For each thousand board feet of lumber produced from sawlogs (which is equivalent to 83.3 cubic feet of solid wood) there is, according to the above table, 80 cubic feet of waste, distributed as follows:

	Cu. ft.
Bark	21.3
Sawdust	22
Edgings and trimmings	14.2
Slabs	14.2
Careless manufacturing and accidents	5.6
Loss in cutting to standards	2.7
Total	80

[2] The Lumber Industry, Part IV, Bureau of Corporations, U. S. Dept. of Commerce; The Production of Lumber in 1913, Bulletin No. 232, U. S. Dept. of Agriculture.

[3] Report of the National Conservation Commission, vol. 2.

After the amount of the bark is deducted there remains in the form of waste 58 cubic feet of solid wood to 1,000 board feet of lumber cut, or 2,320,000,000 cubic feet annually. As the average weight of a cubic foot of air-dry wood is about 35 pounds,[4] this is a total annual waste of 40,000,000 tons. Some of this total annual waste is used for fuel at the mills, or may have a fair market value if the mills are located in centers of population; but it is estimated that over one-half, or 20,000,000 tons, is absolute waste, and that about 15,000,000 tons of this is from coniferous woods.

According to data for 1907 submitted to the Forest Service by the lumber manufacturers, 650 mills were reported to be cutting between 10,000,000 and 25,000,000 feet a year; 161 mills between 25,000,000 and 50,000,000 feet; 39 mills between 50,000,000 and 100,000,000 feet; and 2 mills over 100,000,000 feet annually. This is a total of 852 mills, each of which cuts 10,000,000 or more board feet a year. For 1913, each of 974 mills was reported as cutting this amount. This shows that the number of large operators is increasing instead of decreasing, and that the supply of raw materials is so concentrated as to be available for any use to which it can be put.

THE PRESENT VALUE OF WOOD WASTE.

Most of the wood waste produced to-day is valuable only for fuel for the production of power at the mill. In some places methods of closer utilization have been worked out; but, compared with the total amount of wood waste produced, the quantity of material so utilized is negligible unless the mills are located in or very near large cities.

Most mills produce waste in excess of their own power requirements, and in large mills equipped with especially efficient power plants this excess is from 50 to 65 per cent of the total amount produced. A waste burner, therefore, is almost invariably necessary, and its use involves not only a loss of large quantities of wood, but also a fixed charge for its operation. The cost of burning waste varies widely with the size and efficiency of the mill, but figures gathered by the Forest Products Laboratory indicate that it ranges from 30 to 66 cents a cord. Assuming that 37 cubic feet are burned for each thousand feet board measure of lumber cut, this is a charge of from 11 to 22 cents a thousand feet on all of the lumber cut, and means that the present cost of waste disposal amounts to about $6,000,000 annually, in addition to the value of the wood.

The wood waste available has great potential value, but its utilization has not as yet reached the stage where the waste has much more than a nominal value.

[4] The green weight, log scale, of yellow pine will range from 9,000 to 10,000 pounds to the thousand feet, and the green weight of the lumber produced will range from 4,200 to 4,600 pounds. Allowing for the usual 15 to 20 per cent overrun, we ordinarily get about 4,500 pounds of waste to 1,000 feet of yellow pine cut. The waste from other species will vary in the proportion of their respective weights to the cubic feet or to the thousand feet, log scale.

As will be shown, the production of ethyl alcohol is so far the only process that is applicable to the utilization of average mill-run refuse from the coniferous woods and from a few of the hardwoods. It affords a means of converting waste material into marketable commodities at a profit, provided sufficient quantities of waste material are available in the proper locality and at the proper price. The process is not applicable to the commercial conversion into alcohol of lumber, merchantable timber, or other expensive forms of wood. It, therefore, rests largely with the lumbermen themselves whether they will accept a price for their waste which will make it commercially available, or whether they will demand a price that will make its utilization prohibitive. Cooperation between the sawmill and the distiller is absolutely necessary, for the distiller is dependent upon the mill for his raw material, and the lumberman is dependent upon the distiller for the successful disposal of his waste. During the war, the return of 50 cents a cord for waste was not attactive to many of the lumbermen, with the exception of some in Mississippi, where, however, State laws prohibit the manufacture of ethyl alcohol.

Some sawmill owners have not been willing to tie up their waste on a 10-year contract at the price mentioned, but have preferred to continue for a time to burn it in the speculative hope that some better method of disposal might be found. Such action is, of course, perfectly legitimate and may possibly be the proper one. The alcohol plant costs about as much as the sawmill and its auxiliaries; so that a considerable supply of raw material—enough for at least 10 years—is necessary to justify the initial investment. As the life of the saw mill is continually decreasing, each year that passes reduces materially the prospect of utilizing the sawmill waste.

LIMITATIONS TO THE UTILIZATION OF WOOD WASTE.

The utilization of wood waste, particularly sawmill waste, is limited in a number of ways. The bulkiness of the waste material makes a minimum amount of handling imperative and practically prohibits its transportation, except for short distances and by means of mechanical conveyors, such as belts and fans. The form of the waste is one of the greatest difficulties in the way of its more complete utilization. In sawdust and shavings not only has the length of the wood fiber been reduced, but the fibers have been lacerated to such an extent as to destroy their value for pulp and paper production.

The destructive distillation of sawdust and shavings has not so far been found practicable. There have been two reasons for this: First, the small size of the material makes it so poor a conductor of heat that it can not be charred completely in the forms of retort and kiln in ordinary use; and, second, the charcoal produced is so finely divided that it is difficult to cool and handle and there is no ready

market for it. In addition, the waste as it comes from the mill is usually a mixture of all forms, and any attempt at separation, except perhaps a simple blowing or screening to remove the very fine stuff, will increase the cost of the raw material to a prohibitive figure. Therefore, in any satisfactory process for the utilization of mill waste, it must be possible to handle any and all forms of waste as it comes from the mill.

Except in factories using only one or two species of wood, or in mills cutting only a few similar species, such as the "yellow pine" (longleaf, shortleaf, and loblolly) of the South, the differences in quality and form of the waste have operated against its efficient utilization. This is because many processes, such as pulp and paper making or destructive distillation, require a particular species in order to give a yield and quality of product that will make the processes commercially feasible.

Woods of all species and forms, however, have one point in common—they all contain more or less cellulose, which makes up the fibers of the wood, along with an incrusting substance called lignin. A chemical utilization of this cellulose would overcome the objections stated above as to the form of the material, length of the fiber, and species, provided the amount of cellulose present was sufficient to give a yield of alcohol that could be handled profitably on a commercial scale.

PROCESSES FOR THE MANUFACTURE OF ALCOHOL FROM WOOD.

The processes used for the production of ethyl alcohol from wood may be grouped into two general classes: Hydrolysis of wood into fermentable sugars by the use of dilute acid (preferably mineral acid) as a catalyzer, and solution processes, in which the wood is dissolved in concentrated acid and the diluted solution is then subjected to hydrolysis.

The first process consists, in general, of digesting sawdust or hogged and shredded wood with a dilute mineral acid under 60 pounds or more of steam pressure. This converts part of the wood into a mixture of pentose and hexose sugars. The latter are then fermented into ethyl alcohol.

Processes of the second class, involving the use of concentrated sulphuric acid and in which the wood is actually dissolved by the acid, as in the Ekstrom [5] process, have not received commercial attention, notwithstanding the fact that Flechsig [6] many years ago showed that cotton cellulose could thereby be converted into dextrose and alcohol almost quantitatively. The more recent work of

[5] French Patent No. 380358; German Patents Nos. 193112 and 207354.
[6] Zeit. für Physiol. chemie., 1882.

Willstatter and Feichmeister[7] with fuming hydrochloric acid on cotton and wood has confirmed these results; but in all those experiments the amounts of acid required have been so large that the initial and recovery costs for acid have prevented commercial development.

Whether the source of the fermentable sugars is the cellulose or the lignin of the wood has long been a subject for debate and has also been the occasion of considerable investigation; but the fact remains that a wood cellulose like soda or sulphite pulp has been found to produce about twice as much fermentable sugar and alcohol as the same amount of the original wood, the yields being in proportion to the cellulose content.[a]

HISTORY OF THE PROCESSES.

The first recorded attempts to produce sugars and alcohol from vegetable fiber were those of Braconnot[8] in 1819. From that time until the publication of Simonsen's[9] paper in 1898 little work of value was done.[10] Simonsen's review of the problem is well worth quoting here, because it tersely describes the situation at that time:

> The literature of this problem is imperfect and faulty to a high degree. It contains many inaccurate and impossible statements and contradictions. There is no record of any systematic investigation as to the effect of a variation of the different factors, such as amount of water, pressure, amount of acid, and time in high-pressure inversions. Parallel and comparative experiments on cellulose and wood are also lacking, so no information on the relation of the incrusting substances to the inversion processes is at hand. That these investigations may have been made and their results kept secret is not impossible, since factories have been established. Such researches could hardly have dealt with high-pressure inversion, which has only been carried out practically on a large scale for the last 20 years. Yet the manufacture of spirit from cellulose material by means of inversion under such unfavorable conditions as that over 100 per cent of sulphuric acid was required for the dry wood and the corresponding quantity of calcium carbonate or lime (and taking into account the high price of the material at that time and the length of time required for the process) seems to point to the fact that the inversion of wood will be the method of the future if only a satisfactory process can be found.

Simonsen carried out a long and painstaking research on the subject, in which he investigated both cellulose (sulphite cellulose) and sawdust in a systematic way. As an inverting agent he used sulphuric acid, and from his results concluded that the best conditions for the inversion of sawdust were as follows:

Time of inversion	15 minutes.
Acidity	0.5 per cent H_2SO_4.
Proportion of wood to liquid	1 to 4.
Pressure about	9 atmospheres.

[7] Berichte, 1913, 2401.

[a] Koerner, Zeit. Ang. Chem., 1908, 2353.

[8] Gilbert's Annalen der Physik, 1819, 63, 348.

[9] Zeit. für ang. Chemie, 1898, 195, 962, 1007.

[10] The references to the original literature from 1819 to 1898 will be found in the bibliography at the end of this bulletin.

These conditions gave him a yield of alcohol equal to about 6 per cent of the dry weight of sawdust used, although few fermentation experiments were made.

As was shown later by Neumann,[11] Simonsen's work is contradictory in some respects, because of the fact that only a single experiment was made under each set of conditions. In his work on a large scale,[12] he was generally unable to duplicate the results obtained in the small autoclave cooks. The yields of alcohol varied considerably, although under the most favorable conditions and in a few exceptional cases he obtained yields which were slightly higher than those secured on the small scale. Simonsen's process was patented July 12, 1898.[13] Korner[14] later substantiated Simonsen's yield of 6 per cent and showed further that the yield of alcohol and sugar was in proportion to the cellulose content of the sawdust, straw, and sulphite cellulose used as raw material.

A. C. Classen developed a new process in which sulphur dioxide was the inverting agent, although his first patent[15] covered a mixture of sawdust and concentrated sulphuric acid (50° to 60° B.) in which the mixture was subjected to great pressure in a hydraulic press. In the original Classen process[16] an aqueous solution of sulphurous acid was used, though later Classen obtained three patents[17] in which chlorine, air, or oxygen were used as the oxidizing agents to convert the sulphurous acid to sulphuric acid. Still later he obtained a patent[18] covering the process of treating the wood with sulphuric anhydride, and an additional patent[19] covering the process of heating this mixture to 123° to 135° C.

He also patented[20] the use of a smaller amount of a more concentrated solution of sulphurous acid, claiming that the acid recovery was more efficient when the sawdust in the digester was only slightly moist. In 1914 he patented[21] the use of platinum, ferric oxide, etc., as catalytic agents to convert the sulphurous acid into sulphuric acid in the digester.

The French rights to the Classen process were sold to a M. Taffin, who had experimented for several months at Tolques before the purchase. After satisfying himself that the process was practical, he organized in August, 1904, the Compagnie Industrielle des Alcools

[11] Neumann, Dissertation, Dresden, 1910.
[12] Zeit. für ang. Chemie, 1898, 962.
[13] United States Patent No. 607091. It was also patented in Norway, Austria, England, France, Canada, Hungary, and Germany.
[14] Zeit. für ang. Chemie, 1908, 2353.
[15] German Patent No. 111868.
[16] German Patent No. 118540.
[17] German patents Nos. 118542, 118543, and 118544.
[18] German Patent No. 121869.
[19] German Patent No. 123911.
[20] German Patent No. 130980.
[21] United States Patent No. 1101061.

de l'Ardèche, and built an experimental plant at d'Aubervilliers, in which he planned to determine the most suitable forms of apparatus. After some time the company interested M. André Bernhard, of Lille, one of the largest distillers in France. The capital stock of the company was materially increased, M. Bernhard became manager and director, and the company decided to increase the capacity of the old plant and erect a still larger one in the Vosges. The chemists of the company were meanwhile perfecting a process whereby the acetic acid formed during the cooking of the wood with the sulphurous acid could be recovered along with the major part of the sulphurous acid. In addition, a special type of digester known as a "saccarificateur" [22] was developed. This consisted of a steel cylinder 2½ meters in internal diameter by 2⅓ meters long, through which were spaced 22 tubes 160 mm. in diameter. Outside of each end of the tube heads were flanged boiler-steel jackets, one to receive the live steam from the boiler and the other to take off the condensed steam, the heating being indirect. This type of apparatus will be discussed further in connection with the plant built at Port Hadlock, Wash. Instead of the sugars being extracted in diffusion batteries, water and calcium carbonate were added to the digested sawdust, the whole mass was fermented directly, and afterwards was distilled in the usual type of beer still. Higher yields were claimed for this method than for the extraction method. This plant operated intermittently for a time, a number of runs being made in 1908 on American woods, primarily for the purpose of interesting American capital; but apparently no continued commercial operation resulted on French material.

In 1903, Classen sold the patent rights for America to the Classen Lignum Co. of Chicago, a corporation organized under the laws of the State of New Jersey. This company erected an experimental plant at Highland Park, Chicago, which had a capacity of about 2 tons of dry sawdust a day of 24 hours. Later the company erected a plant at Hattiesburg, Miss., at a cost of about $250,000, to operate on sawmill waste of longleaf pine. A number of mechanical and technical reasons for the failure of this plant have been outlined by Ruttan.[23] The disadvantages of this process were as follows: (1) The great length of time (from 4 to 6 hours) necessary to convert from 1½ to 2 tons of wood; (2) the large quantity of acid required; (3) the prolonged action of so much acid and water in the rotating digester reduced the wood to a very fine powder and formed much sulphuric acid, which, acting on the sugars and other substances present, produced gums and caramels and made the complete extraction of the sugars from the residue very tedious and expensive; (4) the digester was lead lined, and the repair of the buckling and breaking of the

[22] This apparatus is described in detail in French Patent No. 358696.
[23] Jour. of the Soc. of Chem. Ind. 1909, 1290.

lining after every two or three operations proved a source of great delay and expense.

Ewen and Tomlinson, who were associated with the Classen process, began experimenting along new lines to overcome the difficulties that prevented the old process from becoming a commercial success. The results of their researches (United States Patent No. 763472) were: (1) The time of hydrolysis was shortened from 6 hours to 45 minutes; (2) the treated wood waste was obtained in a form which could be quickly and efficiently extracted; (3) a digester was devised which was not affected by the process; (4) the quantity of acid employed was reduced; (5) a large and uniform yield of fermentable sugars was obtained from the wood.

In general, these results were accomplished in the following way: Instead of adding an aqueous solution of sulphur dioxide to the sawdust and afterwards heating this large volume of water, steam was used as a source of both heat and moisture, and the sulphur dioxide was introduced into the digester in a gaseous form. This method shortened the heating period and also decreased the amount of wood that was reduced to a powdered condition, thereby permitting a more complete extraction.

On October 26, 1909, Ewen and Tomlinson were granted a patent protecting the process of producing fermentable sugars from lignocellulose (United States Patent No. 938308). This patent shows that they had given up the use of sulphur dioxide, both gaseous and in solution, and were employing sulphuric acid as the inverting or catalytic agent. A study of the patent reveals the fact that the ratio of water and acid to dry wood which they used was practically the same as in the method patented by Simonsen and referred to above. Ewen and Tomlinson, who were then the engineers and technical advisers of the Standard Alcohol Co., erected a plant at Georgetown, S. C.,[24] for the production of ethyl alcohol from sawmill waste. This plant was later acquired by the E. I. du Pont de Nemours Powder Co., which operated it intermittently until the early part of 1913. A fire then destroyed the main sawmill of the Atlantic Coast Lumber Corporation, and the alcohol plant was not operated until the summer of 1914, when the sawmill had been rebuilt. The alcohol plant has been operated successfully since that time under the Ewen and Tomlinson patents.

Several years ago the Classen Chemical Co. interested western capital in the erection of a plant at Port Hadlock, Wash., on Puget Sound, for the production of ethyl alcohol and cattle food from sawdust obtained from mills at Seattle, Tacoma, Everett, Anacortes, and Port Blakely. The plant was equipped with six digesters of the

[24] For a description, see R. von Demuth, Zeit. für ang. Chemie, 26, 786; also G. Foth, Chemiker Zeitung, 37, 1221, 1297.

same size and shape as those used in the French plant, the idea being to save steam by means of indirect heating. Sawdust and enough water were added through a manhole into the space between the tubes to raise the moisture content to about 45 per cent. Anhydrous sulphur dioxide was then added, and the mixture was cooked at 75 to 100 pounds pressure. The cost of conversion was excessively high, because the corrosion of the digesters was very rapid; the time necessary to heat them by indirect heat was very long; and it was necessary to replace the low-pressure steam with high-pressure steam in the outside jacket in order to prevent the sulphurous-acid gas from leaking out of the digester into the jacket. The extraction equipment was very inefficient, as the modern type of diffusion battery was not used. The plant was very well built, and much of the equipment was imported from France at a high cost. The extracted sawdust was mixed with Hawaiian molasses and was put on the market as a cattle food.[25] It was necessary to dry the extracted material to about 12 per cent moisture, in order to prevent decay, and this gave great difficulty because of explosions of dust in the driers. In addition, the plant was located 80 miles from a railroad, and this distance greatly increased all transportation charges both to and from the plant. This and the very poor design of the digester and extraction equipment were, no doubt, the chief reasons for the failure of the plant.

In the process covered by United States Patents Nos. 985725 and 985728, granted to W. P. Cohoe, of Toronto, Canada, hydrochloric acid is used and preferred as a catalytic agent because of its volatility. A yield of 25 to 28 per cent of fermentable sugars is claimed. It is also stated that the acid can be completely removed from the wood by blowing it out with steam. If this is true, the cost of neutralization is removed. It is also claimed that 1 to 2 per cent of acetic acid can be obtained from the preliminary steaming of hardwood sawdust. In addition, the preliminary steaming is claimed to be of value, because, after the blowing off, the sawdust is of a constant moisture content, irrespective of its initial moisture content. In a later paper Cohoe [26] further describes his work in which hydrochloric acid is used. The following quotations are of particular inter-

[25] The production of cattle food from sawdust has been attempted at another plant in this country, situated at Marinette, Wis. This plant, however, was unsuccessful in marketing the product obtained, since the chief value of hydrolyzed sawdust as a cattle food lies in the carbohydrates that it contains. Carbohydrate foods, as a rule, are the cheapest that the farmer can grow for himself, and usually the only foods purchased are nitrogenous concentrates. The Marinette company was finally forced to add oil cake and similar materials to its product. In addition, the Port Hadlock plant had a great deal of difficulty from spoilage due to the absorption of water and the consequent growth of mold in their product. The material was put on the market under the trade name of "Bastol." A similar material has recently been produced in London by Zimmermann (see article in Jour. Soc. of Arts, 1912, p. 68).

[26] Jour. of the Soc. of Chem. Ind., 1912, 513.

est in the light of more recent work of the Forest Products Laboratory.

1. In view of the fact that the reducing sugars produced by this reaction do not all ferment and also by the fact that the total amount of conversion was not by any means represented by reducing sugar, it occurred to the author that the presence of the hydrolyzing agent during the heating stage might exert a harmful effect upon the final result. To overcome this the digester was filled and heated to the reacting temperatures and then the reacting agent was introduced. This method is the one finally adopted.

2. Given proper preparation of the materials by the preheating and a proper adjustment of phases in the digester, all the time necessary for a successful reaction is that required by a proper mixing of materials. In other words, with proper preparation the reaction itself is practically instantaneous.

3. Throughout all runs the observation made of results on the laboratory scale with regard to the fact that this reaction runs to an equilibrium was confirmed. It has been found by repeated experiment that by a proper adjustment of the phases the concentration at which the equilibrium occurs may be varied.

The yields given in Cohoe's paper, however, do not bear out the claims in his patents, for the paper reports a maximum of 20 per cent of sugars, and the patents claim 25 to 29 per cent of sugars.

After the Georgetown plant was disposed of to the Du Pont Co., the Standard Alcohol Co. underwent a reorganization, some foreign capital was introduced, and a plant designed to produce 5,000 gallons of 188-proof alcohol a day was erected at Fullerton, La. This plant was never operated successfully by the Standard Alcohol Co. because of certain internal financial difficulties caused by the war. Since the introduction of additional foreign capital was out of the question, new American interests acquired a lease of the plant to demonstrate to their own satisfaction the commercial feasibility of the process. These interests, under the name of the Standard Lessee Corporation, operated the plant from July, 1916, until June, 1917. They then purchased the plant and patents under the name of the International Alcohol Corporation. The plant has been operated successfully since the latter part of 1916 up to tbe present time (December, 1918).

The most recent series of patents by Tomlinson, assigned to the Standard Alcohol Co. (United States Patents Nos. 1032440 to 1032450, inclusive) cover the forms of digester, the various processes for feeding the material to the digester, the methods of mixing the acid and wood, and the processes of digestion. The chief points of these patents may be summed up as follows: Patents Nos. 1032441 and 1032442 cover the thorough mixture of the sawdust and dilute acid as they are being fed to the digesters. Patent No. 1032440 is a process patent relating to the method by which the acid liquid is introduced into the digester with the steam after the temperature has been brought to 212° F. but before it has reached 235° F. Patent No. 1032443 covers the recovery of turpentine as well as sugar, and

Patent No. 1032444 the apparatus used in the process. Patent No. 1032445 covers the apparatus for mixing the sawdust and liquid acid (acid in a liquid form) as it is being fed to the digester. Patent No. 1032446 covers other apparatus for this purpose that employs acid in a gaseous form, and Patent No. 1032447 covers the process for the same. Patent No. 1032448 is a continuation of No. 938308. Patents Nos. 1032449 and 1032450 cover the apparatus and process whereby the acid liquor is introduced after the charge has first been steamed, and whereby, it is claimed, a more thorough mixing and greater yields are obtained. This idea of introducing the acid after the steaming is one of the features of Cohoe's earlier patents.

Recently another series of United States patents was taken out by Gallagher and Mork and assigned to the Standard Alcohol Co. Patent No. 1037185 covers the relief of pressure during cooking and claims thereby to eliminate products that inhibit fermentation. Patent No. 1056161 covers the process of cooking at high pressure—at 135 pounds for 15 minutes, then at 70 pounds for 30 minutes—whereby, it is stated, the wood dextrins are converted into dextrose. The claim is made that wood dextrin is converted into dextrose faster than the wood dextrin is produced from lignocellulose under the ordinary conditions of cooking. This is along the same line as the work published three years previously by Neumann, who called the wood dextrins hydrocellulose. Patent No. 1056162 covers the use of waste sulphite liquors as diluting agents for the sulphuric acid used as the hydrolyzing agent. Patent No. 1056163 relates to the use of chlorine either alone or in conjunction with sulphuric acid. The chlorine must be removed before fermentation because of its inhibiting action on yeast. Patent No. 1091327 relates to the use of "beer slop," the residue from the beer still, as a material for diluting the acid used as the hydrolyzing agent. Patent No. 1096030 covers the use of sulphuric acid and hydrochloric acid, or chloride salts with sulphuric acid, as the hydrolyzing agent.

As has been mentioned before, the work of Neumann confirmed that of Simonsen, involving sulphuric acid as a catalytic agent; but Neumann's main work was with gaseous hydrochloric acid. Girard [27] has shown that hydrocellulose is produced from cellulose by the action of gaseous hydrochloric acid, and Neumann has found that sawdust yields some dextrose in addition to the hydrocellulose. Some of the residue of hydrocellulose and sawdust left after the extraction of the dextrose can be converted further into dextrose. Neumann's yields are comparable to those of Simonsen, although by repeated inversions of the residue Neumann obtains a decided increase of total sugars. The individual inversions of the residue, however, do not yield sufficient sugar or alcohol to be of technical

[27] Annales de Chimie et Physique, I, 24, 5 ser., 344.

value. The work of Korner [28] and of Reiferscheidt [29] also substantiates in the main that of Simonsen. Korner attempted to duplicate Classen's work with sulphur dioxide, but could not. Reiferscheidt obtained Classen's yields by using a longer cooking period than that specified by Classen. In addition, several other investigations have been made in which hydrofluoric [30] and other similar acids were used. These investigations are of scientific rather than technical interest, and reference to them may be found in the bibliography.

Different from the processes mentioned above, in which the inversion of the wood is brought about only by heating with mineral acids, is that class of processes in which the cellulose or wood substance is changed to oxycellulose, acid cellulose, cellose,[31] soluble cellulose, or hydrocellulose before the real inversion takes place. Mention has already been made of Girard's work and Neumann's adaptation thereof. Gentzen and Roth [32] patented the use of ozone [33] as an oxidizing agent in conjunction with sulphuric acid. A yield of 34 per cent of dextrose is claimed in the patent, but Korner, in repeating the work, could not obtain any increase in yield over that obtained by sulphuric acid alone.

Korner further investigated the effects of hydrogen peroxide, potassium dichromate, and potassium persulphate in conjunction with sulphuric acid. Hydrogen peroxide increased the yields about 50 per cent above those obtained with sulphuric acid alone, whereas potassium dichromate, potassium persulphate, and ozone all decrease the yields. The use of salts, such as the dichromate and persulphate, may be criticized in that their presence may facilitate the production of secondary compounds.

By prolonged treatment of spruce with concentrated nitric acid, Lindsey and Tollens [34] prepared an oxycellulose which could not be hydrolyzed to a sugar under any condition. If we consider that the salts present in Kroner's experiments exerted no deleterious action and were inert during the inversion, then the results of Lindsey and Tollens seem to be in accord with those of Kroner, in that the oxycellulose prepared by them was the final product of oxidation, and the product obtained by Kroner with potassium dichromate or persulphate was an intermediate product, some of which could be hydrolyzed. Perhaps only a part of the wood was completely oxidized, and the yields of sugar obtained were on the remaining material which had not been acted upon by the oxidizing agent.

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[28] Zeit. für ang. Chemie, 1908, 2353.

[29] *Ibid.*, 1905, 44.

[30] J. J. D'Orlowski, French Patent No. 405187; also L. Spassky, French Patent No. 451268.

[31] G. Ekstrom, United States Patents Nos. 1087743 and 1087744.

[32] United States Patent No. 745676.

[33] See also Charles Doree and M. Cunningham, "The action of ozone on cellulose III action on beech wood (Lignocellulose)"; Jour. Chem. Soc. 103, 677–686; Jour. Chem. Soc. 101, 497–512.

[34] Liebig's Annalen, vol. 267, 341.

The action of hydrogen peroxide would then necessarily be one of pure hydration, in which the production of hydrocellulose was facilitated; for, according to Neumann, since the final yield of dextrose is dependent upon the amount of hydrocellulose originally present or upon the speed of its formation, the production of dextrose from hydrocellulose proceeds at a greater rate than the production of hydrocellulose from cellulose.

From the foregoing it is apparent that, since the publication of Simonsen's work and the obtaining of patents on his process, the production of ethyl alcohol from sawdust has received a very large degree of attention practically all over the world, and large sums have been spent on its technical development. Of the four plants which have been built in this country only two have achieved commercial success, but the failure of the others was due apparently to other things than the process itself.

OUTLINE OF INVESTIGATIONS.

The greatest fault common to all of the work that has been done heretofore is that it was aimed chiefly at an increase in the total yield of sugars, whereas, as will be shown later, such an increase does not necessarily mean a proportionate increase in alcohol yield. Most of the fermentation work done was haphazard and not of the same scientific character as the chemical work. Without accurate fermentations, and, consequently, without complete data, the interpretation of results led to difficulty, because oftentimes total sugar yields might not vary and yet might give different alcohol yields because of variations in the proportion of fermentable and nonfermentable sugars. Since we have no good quantitative chemical means for separating these two classes of sugars and must depend on fermentation, which is a biological process, carefully standardized fermentation experiments are an absolute necessity. The importance of this point, as will be shown later, can not be too strongly emphasized. Simonsen and others after him have contented themselves with an occasional fermentation (usually under conditions that made accurate duplication impossible) to show that some of the sugar obtained was actually fermentable. A careful study of sugar and alcohol relations, especially of the effect of the different variables on that portion of the total sugar that is fermentable, has not, to the knowledge of the writer, been made public heretofore.

Simonsen, Neumann, and other investigators obtained contradictory data because they used as a variable different amounts of an acid solution of constant strength, thereby simultaneously varying both the ratio of water to wood and that of acid to wood. As will be shown in a study of these variables, these ratios are not mutually dependent, and the "acidity" of the solution used for

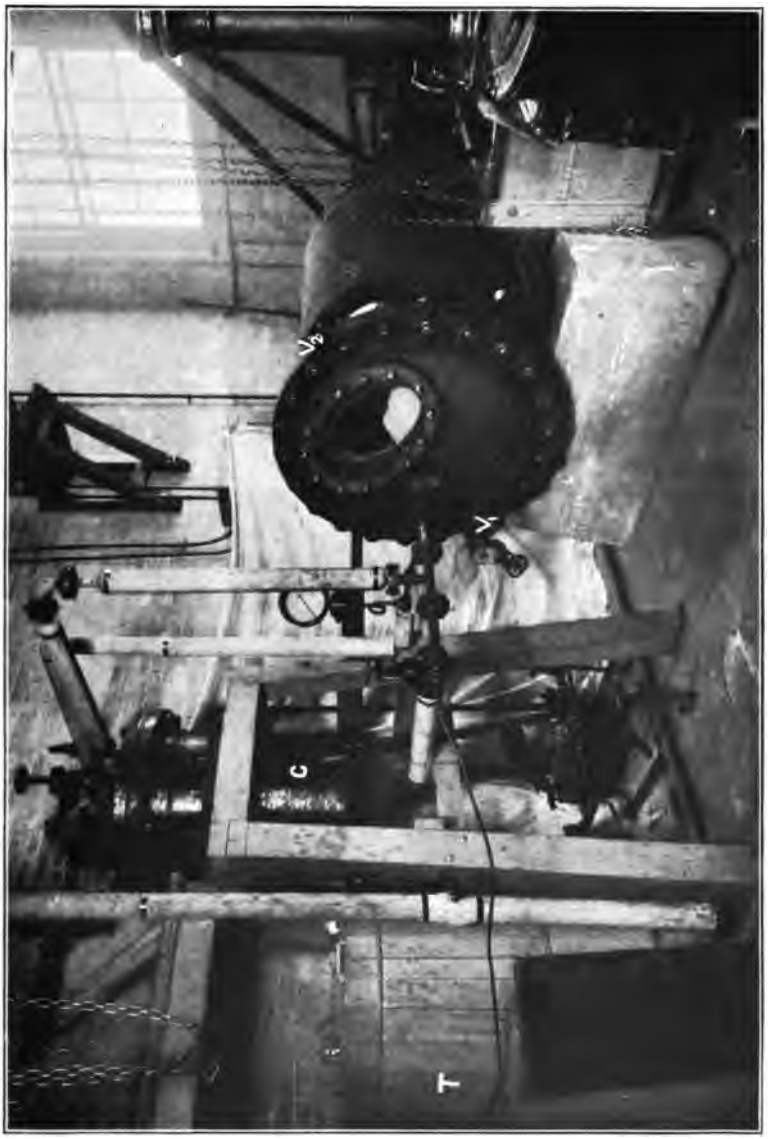
hydrolysis is of little or no importance, except where it varies the actual ratio of acid to wood; the concentration of the catalytic agent expressed in per cent, or other terms, of the dry wood is the decisive factor.

In view of these facts, it was decided to reinvestigate certain of the variables studied heretofore, in addition to such others as might be considered necessary to the technical solution of this problem. This bulletin presents the results of the first part of such a systematic study.

The variables under investigation were: (1) Influence of the temperature and pressure of digestion; (2) length of the time of digestion; (3) ratio of the water to the dry sawdust; (4) ratio of the catalyzing agent to the dry sawdust; (5) concentration of the catalyzing agent in water; (6) size of the sawdust, hogged slabs, etc.; (7) effect of adding the catalyzing agent (acid) after the preliminary heating of the wood; (8) effect of varying the amount of bark in the sawdust; or, more specifically, the tannin and other ingredients in the bark; (9) special chemical treatments other than or in addition to acid catalysis; (10) yields from different species and mixtures; (11) the fermentation variables; (12) steam consumption for each ton of sawdust digested.

APPARATUS AND PROCEDURE.

The apparatus used and the method of procedure in each experiment were as follows: The hydrolysis of the wood was carried on in a rotary digester consisting of a thin cast-iron inner shell lined with acid-proof enamel and an outer shell of steel, the two being separated by several inches. The inside length of the inner shell was about 5 feet, the diameter about 2½ feet, and the total capacity about 22 cubic feet. Steam was admitted simultaneously to the inner shell and to the space between the inner and outer shells, the digester being similar to a steam-jacketed apparatus, except that the inner shell could be readily taken out and replaced. After a cook had been completed, the digester was blown off, the blow-off vapors being condensed in a quartz coil. A cast-iron tank, also lined with acid-proof enamel, was connected with the digester in such a way that its contents might be introduced into the digester when the latter was under pressure. The steam flowed to the inner shell and to the space between the two shells through separate pipes. The one leading to the inner shell connected with the acid tank. All pipes in contact with acid liquor or acid vapor were enamel-lined, and the valves were of special bronze, so as to reduce corrosion to a minimum and avoid as much as possible those complications in fermentation that arise from the presence of iron, copper, and zinc salts. The pressure was



FRONT VIEW OF DIGESTER SHOWING MANHOLE COVERS OFF AND SAWDUST IN INTERIOR.

measured by means of a gauge protected from the acid vapors, and the temperature was shown by a recording thermometer, the bulb of which projected into the sawdust. The digester was filled and emptied through a pair of concentric manholes in the inner and outer shells. The usual procedure was to make the charge of sawdust equivalent to about 100 pounds dry weight. The exact weight and moisture-content were recorded. The dilute acid was then added, the manhole covers were bolted on, steam was admitted, and rotation was begun. Before the temperature reached 100° C., the air in the inner shell and in the space between the two shells was vented to get a more accurate gauge reading. The admission of steam was continued until the desired pressure was reached and then regulated so that the heating period was always 20 minutes, or as near that length of time as possible. The steam was then throttled to maintain the desired pressure for the necessary time.

At the completion of the reaction (or in cooks of 15 minutes or more, 2 or 3 minutes before the time was up) the rotation was stopped and the vapors were blown off and condensed as rapidly as possible. The time of blow-off varied somewhat, depending on the pressure at which the cook was made and the amount of material in the digester. The condensing and cooling capacity of the coil, however, was not equal to the demands made upon it, so that blowing-off the digester took much longer than it should have done—about 1¼ hours from 7 or 8 atmospheres to atmospheric pressure.

The condensed blow-off was weighed and analyzed for volatile acid. The condensation from the steam between the two shells was drained out and weighed. It was also tested qualitatively for dextrose to detect any leakage through stuffing boxes or flanges from the inner shell. Whenever liquor was present in the inner shell, it was drained out through the blow-off valve, after which the digester was rotated so that the manholes were at the bottom, and the sawdust was raked out. After the preliminary series of experiments, this material was centrifuged. The digester liquor, centrifugal liquor, and treated sawdust were first weighed and then analyzed for acidity, total solids, dextrose, etc.

METHODS OF ANALYSIS.

The following methods of analysis were used:

MOISTURE.

About 15 grams of air-dry sawdust or 80 grams of digested or extracted sawdust were weighed into tared crystallizing dishes of glass and dried over night in an oven at 105° C. Although the digested sawdust samples at times charred somewhat, a comparative series in

which the acid was neutralized before drying show no difference between neutralized and unneutralized material.

LEACHED TREATED SAWDUST.

Duplicate 100-gram samples of digested sawdust were weighed into Jena beakers holding 600 c. c., approximately 300 c. c. of water was added, and the beakers were placed on the steam bath. After 30 minutes the solution was filtered, and the filtrate was collected in a 2-liter volumetric flask. More water to the amount of 300 c. c. was then added to the sawdust, and the heating was repeated, a longer time being allowed for each extraction. The total time of extraction was 2 days, two of the extractions extending over night. The filtrate was made up to 2,000 c. c., and the latter was used for analysis.

SUGARS.

Allihn's method of determining the reducing sugars, by means of Fehling's solution, as given in Bureau of Chemistry Bulletin 107 Revised, was followed. The copper oxide was filtered in an asbestos Gooch crucible, washed with hot distilled water, and dissolved with 7 c. c. of concentrated nitric acid. It was then diluted and filtered into a 300 c. c. beaker and electrolyzed after the addition of 5 c. c. of a saturated sodium acetate solution. Hollard's stationary electrodes, consisting of a gauze cathode and a wire-frame anode, were used with a current density of 7.5 amperes at 2.4 volts. After all the copper was deposited, the electrodes were washed in water, alcohol, and ether, dried and weighed, and the dextrose was calculated from the copper numbers in the above-mentioned bulletin.

TOTAL SOLIDS.

One hundred cubic centimeters of the extract was evaporated to dryness in a tared crystallizing dish (in a tannin oven or on the steam bath), then placed in the 105° C. oven one hour, and finally cooled in desiccator and weighed.

VOLATILE ACIDS.

A 100 c. c. sample of the extract was distilled to heavy frothing with 10 c. c. of 85 per cent phosphoric acid. Distilled water to the amount of 100 c. c. was then gradually added from a separatory funnel, as fast as distilled, until the volume of distillate approximated 200 c. c. The distillate was then made up to 250 c. c. A 100 c. c. sample of this distillate was treated in a covered beaker with about 2 grams of mercuric oxide for three hours on the steam bath. After removal from the steam bath, 10 or 15 c. c. of phosphoric acid was added, and the sample was redistilled. Three titrations were then made, as follows: On the original sample, which gave the total

acid, fixed and volatile; on the first distillate, which gave acetic and formic acid; and on the second distillate, which gave acetic acid only.

After the proper samples had been taken, the digested sawdust was placed in the leaching tank, where the sugar was extracted from it with a number of portions of warm water. The liquor from the digester and centrifugal (whenever there was any) and the leach liquors were then combined, neutralized with calcium carbonate and allowed to settle. After settling, the clear liquor was decanted and concentrated to a heavy sirup in a single-effect vacuum evaporator. These sirups were saved until the concentrates from two or three runs were obtained, and then they were diluted to proper strength for fermentation.

YEASTING AND FERMENTATION.

The yeast used was a pure-culture strain of *Saccharomyces cerevisiæ* isolated from a yeast used in a Hungarian distillery producing alcohol from beet-sugar molasses. This yeast is well adapted to the fermentation of sugar solutions obtained from the hydrolysis of wood and is considered to be the best strain available for this purpose.

The yeast was propagated in a beer wort, which was made up as follows: To 100 parts of water, 3 parts of hops were added, and the mixture was boiled vigorously for 15 minutes. The hops were filtered off while hot and from 25 to 35 parts of ground barley malt were added. The mixture was kept at 70° C. for four or five hours until the starch had all been converted, as shown by the iodine test. The malt was then pressed off and the liquid filtered. The filtrate polarized 18° to 20° in a saccharimeter. One liter was then put into a 2 or 5 liter cotton-plugged Erlenmeyer flask and sterilized in an Arnold sterilizer on three successive days. A small drop of the culture yeast kept in sterile sugar solution was added, and the fermentation was allowed to go to completion in about four or five days at 30° C., after which the resulting beer was poured off the yeast, and a 10 per cent sterile sucrose solution was added. About 10 c. c. of the yeast solution was then placed in a 50 c. c. sterile Florence flask, and these samples were used for starting the yeast. All transfers were made and similar work was done in a Hansen culture cabinet under sterile conditions.

The more recent practice for control work at the Forest Products Laboratory has been to propagate the yeast in a Pasteur flask in beer wort made as above, from which it is transferred to Freudenreich flasks which have side necks. Under these conditions it has been possible to propagate a yeast of strict purity, and all possible sources of contamination have been eliminated. The yeast will keep for long

periods in the sugar solution, and, therefore, a three or four months' stock can usually be made up at one time.

When a series of fermentations was ready to be run, the small yeast sample in either the 50 c. c. Florence flask or the side-neck Freudenreich flask was added to 50 c. c. of 12° Brix sterile molasses, which was kept at 30° C. ±0.5° C.[35] for about 24 hours. Of this solution 10 c. c. was then added to 250 c. c. of 18° Brix molasses after about 18 hours at 30° C. Of this sample 50 c. c. was transformed to 1,500 c. c. of 18° Brix molasses, which was allowed to work off to about 12° Brix in 15 to 18 hours, when it was ready for use as the starting yeast.

Meanwhile a sprout mash was made up of 8.5 grams of malt sprouts and 2.5 grams of ammonium sulphate, boiled for 15 minutes in 250 c. c. of the wood-sugar solution to be fermented. This was cooled to 30° C., and 75 c. c. of the starting yeast (in 12° Brix molasses) was added. After 6 hours the mash was washed into a 20-liter bottle (a half carboy) with 100 c. c. of the wood-sugar solution. The latter varied in concentration from about 10° to 13.5° Brix, the average being 12° to 12.5°. The exact concentrations for each fermentation are shown on the fermentation sheet. After 3 hours 100 c. c. of wood-sugar solution was added; after 3 hours, 200 c. c.; after 3 hours, 200 c. c.; after 2.5 hours, 400 c. c.; and each hour thereafter, 400 c. c., until a final volume of 2 gallons (7,570 c. c.) was made up. The general plan of starting and filling the fermenters is shown in the following table:

Fermentation No. 2. Cooks 29, 33, 34, 35, 36, 37, 38, and 39. Starting yeast, 12° Brix.

		Volume added.	Total volume.			Volume added.	Total volume.
		C. c.	*C. c.*			*C. c.*	*C. c.*
Sept. 24	9.30 a. m.[1]	250	250	Sept. 25	9.00 a. m.	400	3,650
	3.30 p. m.	100	350		10.00 a. m.	400	4,050
	6.30 p. m.	100	450		11.00 a. m.	400	4,450
	9.30 p. m.	200	650		12.00 m.	400	4,850
Sept. 25	12.30 a. m.	200	850		1.00 p. m.	400	5,250
	3.00 a. m.	400	1,250		2.00 p. m.	400	5,650
	4.00 a. m.	400	1,650		3.00 p. m.	400	6,050
	5.00 a. m.	400	2,050		4.00 p. m.	400	6,450
	6.00 a. m.	400	2,450		5.00 p. m.	400	6,850
	7.00 a. m.	400	2,850		6.00 p. m.	400	7,250
	8.00 a. m.	400	3,250		7.00 p. m.	320	7,570

[1] Time sprout mash was set.

The above scheme was intended to duplicate as nearly as possible the times at which the different amounts of the solutions would be added from the different yeast tubs to the fermenters on a commercial scale. The first steps up to 3 a. m. are acclimating and propagating the yeast in the yeast tubs, and the final transfer into the fermenters is made at 3 a. m. From then on it takes from 12 to 18 hours in

[35] All fermentations were made in a fermentation room, the temperature of which was kept constant at 30° C. ±0.5° C., and which could be sterilized and kept in a clean condition.

commercial practice to fill the fermenters. The length of this period depends on the size of the coolers and on the temperature of the cooling water and of the neutral juice to be cooled; for the extraction of sugar is carried on either at 70° to 80° C. or at 40° to 45° C. in the diffusion battery, and the solutions cool only slightly while being neutralized and settled.

At 9.30 a. m., September 26, the first-day Brix reading was taken; and at 9.30 a. m., September 29, the beers were distilled for analysis. This gave a fermenting period slightly in excess of 96 hours (the time allowed by the Bureau of Internal Revenue for a sour-mash fermentation), for the filling of the fermenters was actually begun at 3 a. m., September 25, instead of at 9.30 a. m., September 24. However, the error introduced is practically of no significance, for the attenuation on the fourth day is usually only 0.2° Brix at the most. The work was greatly simplified by this scheme, and most of it could be done in the usual laboratory working hours.

As will be noted on the sugar and alcohol yield sheets, the fermentation efficiencies are high; that is, higher than the 90 to 94 per cent that would ordinarily be obtained, the chief reasons for this are to be found in: (1) The alcohol added along with the starting yeast; (2) the unfermented molasses in the starting yeast, which subsequently fermented; [36] (3) errors in sugar determinations; (4) errors in sampling.

The fermentable sugars and fermentation efficiencies are calculated as follows, and the effect of the above errors and their magnitude will be shown. The wood-sugar solution obtained after neutralization and settling, and hereafter called the neutral juice, is analyzed before and after fermentation. The solution after fermentation is called the beer. The sugar is always expressed in grams of dextrose to the liter, although it was actually a mixture of dextrose, possibly other hexoses (as in the case of western larch), and pentoses. The following formula gives the percentage of the total sugars that are fermentable, expressed as dextrose:

$$\frac{\dfrac{\text{Dx. in neutral juice, grams per liter}}{\text{Sp. gr. of juice}} - \dfrac{\text{Dx. in beer, grams per liter}}{\text{Sp. gr. of beer}}}{\dfrac{\text{Dx. in neutral juice}}{\text{Sp. gr. of juice}}} \times 100 = \text{Percentage of total sugars fermentable.}$$

The fermentable sugars are defined as all sugars that have disappeared during fermentation, whether the resulting product is alcohol or not. If the product is not alcohol, it will appear in the fermentation efficiency figure. If the sugar in the neutral juice before fermen-

[36] The 18° Brix molasses worked off to about 12° Brix when it was added to the sprout mash. On the fourth day, when a sample of the yeast was distilled for analysis, the Brix readings ranged between 4° and 5°.

tation, expressed in percentage, is multiplied by the percentage of sugar fermentable, and by the constant 0.5111 (which is the amount of alcohol theoretically possible from 1 unit of dextrose), the result is the amount of alcohol theoretically obtainable from the sugar present in the neutral juice. The actual percentage by weight of alcohol in the beer divided by this theoretical alcohol figure will give the fermentation efficiency.

The first and second causes for the high fermentation efficiencies may be grouped together. As shows on the fermentation record sheets, the starting yeast will average 6 per cent of alcohol on the fourth day, which is equivalent to 4.5 c. c. of absolute alcohol. A 12.5° Brix neutral juice will give a beer averaging 2.4 per cent of alcohol, the 2 gallons being equivalent to 181.7 c. c. of absolute alcohol. The alcohol from the yeast is, therefore, 2.48 per cent of the total alcohol and causes the fermentation efficiency to be high by approximately this amount. In beers having less than 2.4 per cent of alcohol the error will be greater, and in beers of greater alcohol content, the error will be correspondingly less. The figure obtained for fermentation efficiency is very important for comparative purposes; and, as the error is nearly a constant one, no corrections were made in calculating these values in order to eliminate the alcohol derived from the yeast. In addition, it permits of the expression of yields in the way they would be obtained commercially, for, in either case, commercial or experimental, about 1 per cent by volume of the total mash consists of the starting yeast solution.

The magnitude of the errors involved in the sugar determination is more difficult to determine. In addition to sugars, there are other reducing substances present. These are principally aldehydes and formates, for it is known that considerable quantities of formic acid are present before neutralization. Further, although the sugar is determined and calculated as dextrose (*d*-glucose), the sugar is actually a mixture of this hexose, sometimes with pentoses and sometimes with other hexoses. Moreover, the ratio of these sugars to each other varies in the different samples taken, and, although after fermentation the sugars consist entirely of pentoses and nonfermentable hexoses, they are determined and calculated as dextrose. This opens two possibilities for error: First, varying quantities of pentoses affect the accuracy of the actual dextrose determination; second, the reducing powers of sugars other than *d*-glucose are not the same as the power of *d*-glucose.

Stone [37] and Browne [38] differ as to the relative reducing powers of arabinose and xylose as compared with *d*-glucose, but both writers

[37] Stone, W. E., Berichte 23, 3796.
[38] Browne, C. A., Jour. of the Am. Chem. Soc. 28, 439.

show that the first two are not the same as *d*-glucose in reducing power. Browne says:

> The statement has been made that in a mixture of sugars the reducing power of the individual sugars is somewhat modified by the other members present. The writer has subjected this statement to a thorough test and can discover no such influence.

However, no wide ranges of varying sugar concentrations were tried by Browne, and therefore this point was checked up at the Forest Products Laboratory with mixtures of arabinose, xylose, and *d*-glucose, and no modifying influence in mixtures was found at widely varying concentrations. Since there is no mutual influence, it is possible to correct the analyses after fermentation, if desired, for the nonfermentable sugars may in most cases be regarded as pentoses such as xylose. As the ratio of the reduction factors of xylose and dextrose, as found by Browne and corroborated by the work at the Forest Products Laboratory, was 0.983, no great error has been introduced, because the reducing power of xylose is so nearly that of dextrose.

The main error due to sampling, other than unavoidable ones arising from the sampling of large quantities of material, has been found and in a great measure overcome. On the sugar and alcohol yield sheets it will be noticed that up to cook 43 it was necessary to discard one or more of the fermentations in many of the cooks, because of poor yields or abnormal fermentation efficiencies. The reasons for these discrepancies were apparent. After the sugar was extracted from the wood and the acid solution had been neutralized, the clarified, settled neutral juice was concentrated to a heavy sirup in vacuo and stored as such. In the different cooks, varying amounts of sludge were precipitated when the neutral juice was concentrated. This sludge consists mainly of calicum sulphate, some calcium acetate, and calcium formate, with possibly some crystallized sugar. When a fermentation was to be made, the heavy sirup was diluted with water to give a solution of about 12.5° Brix. Previous to cook No. 43, samples of the 12.5° Brix juice were taken for analysis along with the sludge remaining in the carboy before sterilization. After that time the samples were made up and allowed to stand all night; the clear juice was then siphoned out into a clean 5-gallon bottle and given two intermittent sterilizations. The sample for analysis and the final Brix reading were taken at the same time that the 240 c. c. sample was taken for making up the sprout mash. This apparently obviated all of the former difficulties, and but few fermentations were discarded after this scheme was inaugurated. In addition, the sugar data in each run were much more concordant.

A constant-temperature bath, which will regulate to ±0.05° C., also materially assisted in the accuracy of the alcohol determination. The beers were cooled to 20° C. Portions of 100 c. c. each were taken for distillation, to which were added 50 c. c. of distilled water and about 5 grams of precipitated calcium carbonate, along with 3 or 4 drops of high-boiling paraffin oil to prevent foaming. A portion of 100 c. c. was distilled over and caught in a volumetric flask. If a drop or two of paraffin oil came over, it was readily removed with a small strip of absorbent paper toweling. The 100 c. c. of distillates was then placed in the 15.6° C. constant-temperature bath; after it came to temperature the volume was made up, and the specific gravity was determined by means of a Boots double-wall vacuum pycnometer. In this way the alcohol-content of the beer could be determined very accurately. Although only a small amount of calcium carbonate was necessary to neutralize the volatile acid present, as can be shown by a redistillation of the first distillate, an excess of calcium carbonate—about 5 grams—was used to prevent bumping.

Beginning with fermentation No. 10, the total solids in the neutral juice and beer were determined. This was done in an attempt to correlate the specific gravity, Brix, and sugar data in the neutral juice, and also to give a check on the fermentable sugars and alcohol determinations. It has been found, for instance, in the fermentation of waste sulphite liquors that sufficient volatile compounds, mostly sulphur compounds, distill over in the alcohol determination to make this determination from the gravity of the distillate practically worthless. The addition of alkali and the redistillation helped, but even then there was not much correlation between the alcohol as determined and the sugar data. When determinations were made of total solids, however, it was found that, if the difference in the two determinations before and after fermentation were assumed to be alcohol and carbon dioxide, and if the alcohol were calculated from that difference, the results agreed quite well with the other analytical data and especially with the yields of alcohol obtained commercially or on a large scale experimentally. The data obtained at the Forest Products Laboratory on total solids, however, have not been of such assistance, and frequently the total solids do not even follow the specific gravity or Brix readings; much less do they give a good indication of the alcohol yields, as the following table will show:

Cook 56.

Mash before fermentation.					Beer.								
Fermentation No.	Sp. gr. at 15° C.	Brix.	Total solids.	Dextrose per liter.	Sp. gr. at 15° C.	Brix.	Total solids.	Alcohol by weight.	Alcohol from total solids.	Difference in total solids.	Fermentable sugar, average.	Alcohol yields, average.	Alcohol per ton.
			Per ct.	*Grms.*			*P. ct.*	*Per ct.*				*P. ct.*	*Gals.*
16.....	1.0514	12.4	9.567	65.20	1.0270	6.8	5.842	2.390	1.899	3.715			
16.....	1.0509	12.4	8.858	64.60	1.0268	6.8	5.848	2.395	1.548	3.010			
17.....	1.0475	12.0	9.428	57.34	1.0268	6.8	5.873	2.259	1.817	3.555			
17.....	1.0498	12.4	9.978	60.10	1.0278	7.2	6.160	2.345	1.952	3.818	77.15	8.295	25.09
18.....	1.0487	12.3	11.110	66.52	1.0262	6.6	6.070	2.543	2.576	5.040			
20.....	1.0429	10.7	8.606	56.90	1.0227	5.8	5.278	1.968	1.701	3.328			
20.....	1.0542	13.1	10.750	71.29	1.0287	7.1	6.493	2.590	2.176	4.257			

Cook 57.

17.....	1.0529	13.1	10.614	70.24	1.0279	7.2	6.264	2.558	2.223	4.350			
17.....	1.0509	12.5	10.076	66.32	1.0263	6.8	6.023	2.543	2.072	4.053			
18.....	1.0463	11.5	9.962	62.02	1.0247	6.3	5.781	2.318	2.137	4.181	78.90	8.222	24.87
18.....	1.0400	10.0	8.705	52.26	1.0213	5.3	4.948	1.909	1.920	3.757			
19.....	1.0474	11.7	8.539	60.98	1.0240	6.3	5.805	2.266	1.398	2.734			
19.....	1.0472	11.5	8.465	60.48	1.0246	6.3	5.951	2.274	1.314	2.514			

Cook 58.

18.....	1.0468	11.7	10.996	75.81	1.0258	6.5	6.204	2.218	2.449	4.792			
18.....	1.0497	12.4	11.006	81.48	1.0275	7.0	6.484	2.117	2.311	4.522			
19.....	1.0523	12.7	9.679	83.15	1.0285	7.3	7.196	2.421	1.780	3.483	60.48	6.768	20.47
19.....	1.0540	13.3	10.598	87.19	1.0300	7.6	7.453	2.500	1.608	3.145			
20.....	1.0553	13.2	11.180	87.79	1.0300	7.5	7.063	2.456	2.104	4.117			

In this table two extremes of fermentable sugars were chosen, namely, cooks Nos. 56 and 57, with high fermentable sugar and alcohol yields, and cook No. 58, with low fermentable sugar and alcohol yields. There were always some alcohol yields, as calculated from the total solids, that were above, as well as some that were below, those actually determined by distillation. It seems, therefore, that the figure for total solids is no criterion, especially when the ratio of sugar to total solids given on the digester record sheet is examined. Extreme cooking conditions, such as high acid, high pressure, and long-time cooks, increased the production of total solids other than sugars. In these experiments, however, the total solids were determined in the acid extracts. After the latter had been neutralized, as in the neutral juice before fermentation, the proportion of sugars to total solids was still lower because of the large amount of calcium salts of the organic acids present. Because of the latter, apparently, there was a large variation of alcohol, as calculated from the total solids and by distillation. The Brix and specific gravity sometimes varied with the total solids and sometimes with the sugars. In cook No. 56, fermentation No. 17, there was a 12°

Brix juice with 57.34 grams per liter of dextrose; and in the same cook, fermentation No. 20, there was a 10.7° Brix juice, with 56.90 grams per liter of dextrose. The whole question here seems to be one of the solubility of the sludge at the time the neutral juice is diluted before fermentation. Commercially no such variation would be obtained. Concentration of the neutral juice in an evaporator is unnecessary, for the reason that a juice of proper concentration for fermentation is obtainable directly from the diffusion battery.

As outlined previously, the variations in sugar data in the different fermentations seem to have been caused by the presence of sludge when the sample was taken. With the adoption of the method by which the clear neutral juice was siphoned from the sludge before sampling, these variations practically vanished. Cook No. 41, however, affords two check sets of fermentable sugar data with wide variations, as shown in the following table:

COOK 41.

Fermentation No.	Total sugar, per cent of dry wood.	Per cent of total sugars fermentable.	Fermentation efficiency.	Alcohol yield.	
				Per cent of dry wood.	Gallons absolute. per ton.
4	23.09	32.95	102.66	3.992	12.075
5		57.18	89.14	6.690	20.235
6		56.80	95.46	6.399	19.355
7		47.20	101.06	5.629	17.026
8		45.46	101.90	5.466	16.533

Fermentation No. 4 is evidently of no value. This was found to be true of most of the other cooks included in this fermentation, although no reason can at present be assigned for it, as the acidity and attenuation of the yeast seemed to be normal. Fermentations Nos. 5 and 6, however, show an average of 56.99 per cent of sugars fermentable, and fermentations Nos. 7 and 8 an average of 46.33 per cent of sugars fermentable. Both fermentations show fairly good checks and apparently normal fermentation.

The first of the above averages was chosen as the cook average, for, as will be shown later, that point is on the curve in the series in which cook No. 41 belongs and is, no doubt, the proper value. The reason for the second set of results is still unknown. It is to be regretted that lack of material prevented further fermentations on this cook, as the above is the only case in which a condition of this kind was noticed.

The acidity of the yeast, neutral juice, and beer is expressed in degrees, each degree being the number of cubic centimeters of N/10 alkali required for 20 c. c. of solution, phenolphtalein being used as an indicator. Another unit that is frequently used in this country is

based upon the number of cubic centimeters of N/10 alkali required to neutralize 10 c. c. of this solution and is, consequently, equivalent to two of the above-mentioned degrees. In general, both the yeast and the neutral-juice acidity increased about 4° during fermentation. However, as outlined previously, the yeast was propagated in molasses which had not been sulphited, and in the course of several years the acidity of the molasses increased about 15°. A microscopic examination showed the presence of both bacteria and cocci, and the increase in acidity was probably caused by both of these. Sometimes the acidity increased during the fermentation almost double the average amount without doing any apparent harm.

RESULTS.

The first series of digestion experiments was more or less preliminary in character, as it was necessary to overcome a number of technical difficulties growing out of unusual conditions that required a combination of high pressure and high temperature in the presence of an acid. It required further time to organize and coordinate the work properly, especially in view of the fact that each successive run or pair of runs represented different experimental conditions. The fermentation equipment was not ready at the time; and, although some fermentations were necessarily made, no great confidence was placed in the value of the results. The total sugar data may be considered accurate, however, in view of the fact that confirmative runs were made later, in which the necessary fermentations also were carried out.

The complete data for all the runs, beginning with No. 21, will be found in the Appendix. These include the digester record, fermentation record, sugar and alcohol yields, and volatile-acid yields. An analysis of the various results obtained is given under the different subheadings that follow.

EFFECT OF TEMPERATURE AND PRESSURE.

The effects of various temperatures and pressures are grouped into two classes—the first series, in which the ratio of water to wood was 400 per cent (four times as much water as dry wood), the ratio recommended by Simonsen; and the second series, in which the ratio of water to wood was 125 per cent. In the first series the ratio of acid to wood was 1.8 per cent, which was found by Simonsen to yield the best results; and in the second series the ratio of acid to wood was 2.5 per cent. In addition, the first series was run with two time variables—first, a 15-minute cooking period, and, second, an instantaneous (0-minute) cook. The results are given in the following tables and curves.

Series Ia.

400 per cent of H_2O; 1.80 to 1.85 per cent of H_2SO_4; cooking time, 15 minutes.

Cook No.	Pressure (atmospheres).	Yield of total sugars (per cent of dry wood).
8	4.25	14.29
7	6.3	20.48
21	[1] 7.1 to 7.3	21.50
18	7.5	22.85
5	7.75	21.54
11	8.1	20.05
12	9.3	11.58

[1] The steam pressure varied between these points and it was not possible to keep the digester pressure uniform.

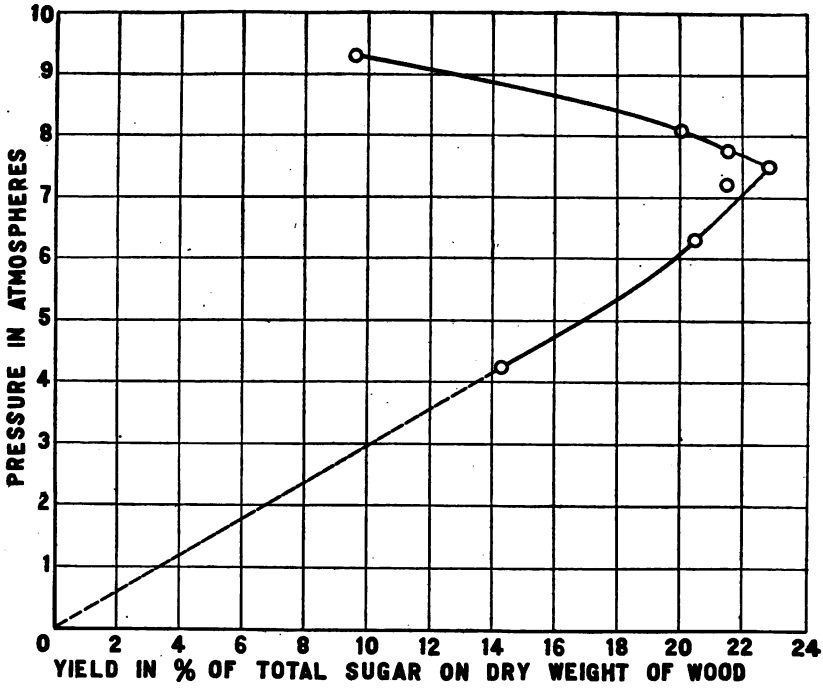


Fig. 1.—Series Ia, showing the variation of yield of total sugars with varying pressures of cooking. Cooking period, 15 minutes.

Series Ib.

400 per cent of H_2O; 1.80 to 1.85 per cent of H_2SO_4; cooking time, 0 minutes.

Cook No.	Pressure (atmospheres).	Yield of total sugars (per cent of dry wood).
20	6.5	18.34
15	7.5	22.59
16	7.5	22.70
19	9.0	21.29

SERIES II.

125 per cent of H_2O; 2.5 per cent H_2SO_4; cooking time, 15 minutes.

Cook No.	Pressure (atmospheres).	Yield of total sugars.	Per cent of total sugars fermentable.	Alcohol (per cent of dry wood).
58	6.0	22.82	60.48	6.768
(2)	7.5	23.50	69.36	8.260
57	9.0	21.08	78.90	8.222

[2] Not an actual cook. The data are interpolated from cooks Nos. 45, 46, and 47, which are similar to the above but for 0, 10, and 20 minutes. The 15-minute cook was not made, but may easily be derived from the above series.

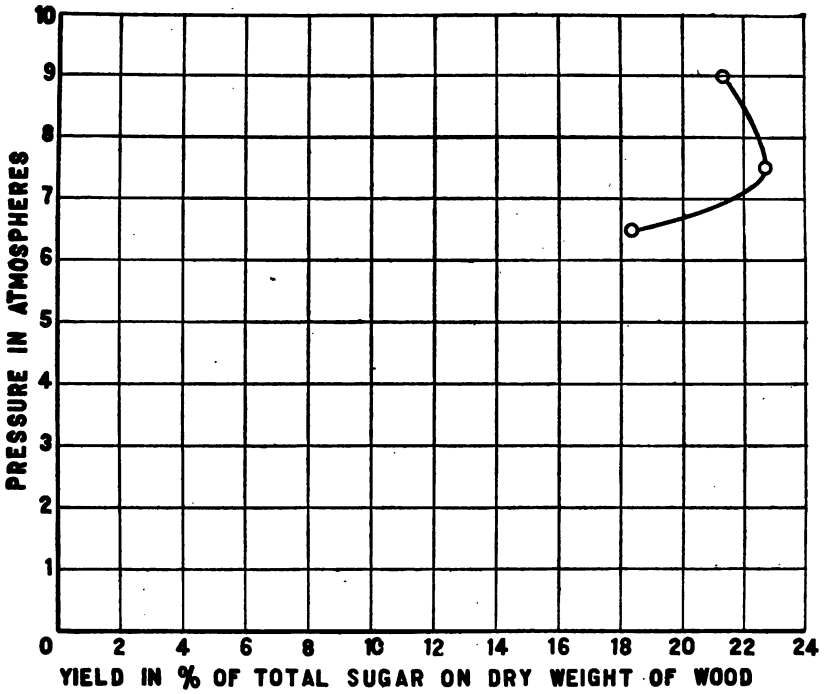


FIG. 2.—Series Ib, showing the variation of yield of total sugars with varying pressures of cooking. Cooking period, 0 minutes (instantaneous).

From the above results a maximum is observed in total sugar yields at 7.5 atmospheres gauge-pressure and the temperature corresponding thereto, which was 174° C. or 344° F. Above this point decomposition set in, and if I*a* series is compared with I*b*, it is seen that this decomposition was naturally much greater in the 15-minute cook than in the instantaneous (0-minute) cook. Below the above temperature, as was to be expected, the yield was not so great, because the speed of reaction and the yield of the final product is a function of the temperature. The higher the temperature the greater the speed of the reaction and the greater the yield in a given time, so

long as decomposition does not become appreciable; but the following table[39] on the decomposition of dextrose in sulphuric-acid solution shows a marked decomposition above 175° C. (1 gram of dextrose in 25 c. c. of sulphuric acid of various concentrations heated for 30 minutes at the indicated temperatures.)

Per cent of sulphuric acid.	Per cent of undecomposed dextrose.			
	At 150° C.	At 160° C.	At 175° C.	At 185° C.
0.1	100.0	94.4	94.2	88.8
.5	96.1	92.7	91.6	50.0
1.0	94.4	83.3	86.6	33.3
1.5	88.8	80.5	55.5	31.1
2.0	87.7	75.0	37.2	5.5
2.5	86.6	72.2	33.3	5.0
3.0	83.3	71.0	25.0	2.7
5.0	80.5	38.8	5.5	.0

Neuman calls 175° C. the "critical point" and claims that technically there is no need of investigating the production of sugars at higher temperatures. The results of the work at the Forest Products Laboratory support this statement.

Series II, however, shows that even though the total sugar yield decreased at temperatures higher than that corresponding to 7.5 atmospheres, the portion of the total sugars which was fermentable increased sufficiently to balance the decrease in total sugars, and hence the final alcohol yield was practically the same at 7.5 and 9 atmospheres. As outlined before, the necessity for complete data is at once apparent, and much of the value of series I*a* and I*b* would be lost if the data for series II were not at hand. The increase, or rather, the percentage of increase, in fermentable sugars may be explained in part by the fact that there is a selective decomposition; that is, the pentose or reducing substances other than the hexose present are more easily decomposed at the high temperature than is the dextrose. The following table of volatile-acid yields shows that there was greater sugar decomposition, with consequent formation of formic acid, at 9 atmospheres than at 6 atmospheres.

Cook No.	Pressure (atmospheres).	Acetic acid (per cent of dry wood).	Formic acid (per cent of dry wood).	Ratio.	Total acid (per cent of dry wood).
58	6.0	2.47	0.399	6.19 : 1	2.869
57	9.0	3.53	.659	5.36 : 1	4.189
47[a]	7.5	2.62	.340	7.71 : 1	2.960
46[b]	7.5	2.36	1.450	1.63 : 1	3.810

[a] 10-minute cook. [b] 15-minute cook.

[39] Neumann, Dissertation, Dresden, 1910, p. 31.

A similar increase in formic acid is shown in the curve for series I*b* on page 50.

As no data were available in the literature on the decomposition of pentoses under the conditions that obtained in these experiments, a number of autoclave cooks were made in which both pure dextrose and pure xylose in sulphuric-acid solutions were used. The solutions were made in such a way that the concentrations of sugar would be comparable to those obtained in the regular runs, and the data from these cooks are given in the two following tables:

Solution of 0.8 of a gram of xylose in 100 c. c. of 0.5 per cent sulphiric acid, heated to 112 pounds in 20 minutes. Held at 112 pounds for 15 minutes.

	I.	I1.	III.
Original xylose.....grams..	0.4000	0.4000	0.4000
Residual reducing sugars.....do....	.2268	.2044	.2056
Residual reducing sugars, per cent of original.....	56.7	51.15	51.4
Acetic acid.....grams..	None.	None.	None.
Formic acid.....do....	.0232	.0280	.0280

Solution of 4 grams of dextrose in 100 c. c. of 0.5 per cent sulphuric acid, heated to 112 pounds in 20 minutes. I, held at 118 pounds for 15 minutes; II, held at 112 to 116 pounds for 15 minutes.

	I.	II.	III.
Original dextrose.....grams..	1.000	2.000	.....
Residual reducing sugars.....do....	1.072	1.472	.....
Acetic acid.....do....	.0046	.0070	.....
Formic acid.....do....	.0926	.0766	.....

In addition to the above two series, one cook was made on an aqueous solution of dextrose instead of a sulphuric-acid solution and with the following results:

Aqueous solution of 4 grams of dextrose in 100 c. c. of solution, heated to 112 pounds in 20 minutes. Held at 112 pounds for 15 minutes. Reducing sugar 0.1891 gr. cu.=0.09685×10×4=3.874 grams of dextrose per 100 c. c.

Acetic.	Formic.	Total.
0.70 c. c. .70 c. c. .00406 g.	0.25 c. c. .25 c. c. .0011 g.	0.95 c. c. .95 c. c. .....

The above data confirm the experimental results obtained in cooks in the series mentioned and are also extremely interesting, as it is found that approximately 50 per cent of xylose was decomposed under the conditions used, even in a solution containing only 0.8 of a gram per 100 c. c. of 0.5 per cent sulphuric acid. Furthermore, only formic acid is produced, with no acetic acid whatever. A dextrose solution having five times the concentration of dextrose showed on an average 64 per cent of the original dextrose remaining; and, although formic acid was the main constituent of the total volatile acid, some acetic acid was formed.

Another series of experiments was made on autoclaving the neutralized juice before and after fermentation. The results of these experiments are given in the following tables. It is of particular interest to note here that a greater sugar decomposition occurred in the autoclave of both the neutral juice and the beer when no sulphuric acid was added than when sulphuric acid was added before autoclaving. The volatile-acid figures, although somewhat erratic, show a decided tendency toward an increase of volatile acid, although here we have a mixture of conditions in which, undoubtedly, a number of secondary reactions take place, and some of the combined acids that are present either as calcium salts or organic combinations are liberated during the autoclave process.

Autoclave cooks on fermented and unfermented wood-sugar extracts.

No.	Reducing sugars per 100 c. c.	Acetic acid per 100 c. c.	Formic acid per 100 c. c.	Sulphuric acid per 100 c. c.	Total volatile acid.
Neutral juice:					
74-6 (1)	39.72	0.248	0.380	.....	0.628
74-6 (2)	18.148	.356	.582	.....	.938
74-6 (3)	31.824	.263	.540	.....	.803
74-6 (4)	36.08	.333	.338	.....	.671
Beer:					
74-7 (1)	17.99	.387	.665	.....	1.052
74-7 (2)	7.70	.480	.754	.....	1.234
74-7 (3)	12.29	1.208	.095	.....	1.303
74-7 (4)	13.11	.341	.671	.....	1.012
Neutral juice:					
73-6 (1)	41.29	.713	.184	.....	.897
73-6 (2)	14.24	.883	.404	.....	1.287
73-6 (3)	22.04	.868	.238	.....	1.116
73-6 (4)	29.03	.527	.439	.....	.966
Beer:					
73-7 (1)	41.624	1.038	.392	.....	1.430
73-7 (2)	12.94	1.418	.540	.....	1.958
73-7 (3)	20.75	1.356	.410	.....	1.866
73-7 (4)	19.01	1.286	.475	.....	1.761

(1) original; (2) original autoclaved, 112 pounds for 15 minutes; (3) original plus 0.5 per cent of sulphuric acid autoclaved, 112 pounds for 15 minutes; (4) original plus 0.5 per cent of sulphuric acid autoclaved, 112 pounds for 15 minutes.

The experimental procedure covering the previous series of autoclave cooks on fermented and unfermented extracts, also sugar solutions in both water and sulphuric acid, was carried on as follows: Fifty cubic centimeters of the solution was put into a pear-shaped, porcelain-stoppered, rubber-gasketed pressure flask of glass, which was put into an autoclave, the flask being surrounded by water. The autoclave was gas heated, and steam pressure was turned into the autoclave so fast as to make the autoclave cooks comparable with the digester cooks. As the flasks were stoppered, none of the volatile acids could escape, and they were determined along with the sugars in the solutions after they were cooked in the autoclave.

Comparing these yields with those shown above for series II, it is seen that the yields were higher at 6 and 9 atmospheres, no doubt on account of different amounts of water present. For all technical

purposes, therefore, there is no advantage in exceeding 7.5 atmospheres (112 to 115 pounds per square inch gauge pressure), for above this point decomposition of sugar sets in. The decomposition of the fermentable sugars was apparently not so great as that of the nonfermentable sugars, and the final alcohol yield was, therefore, not greatly affected; but the increased amounts of volatile acids formed are undesirable because of the possibility of an inhibiting action during fermentation.

LENGTH OF TIME OF COOKING.

When the pressure of 7.5 atmospheres was used as a constant, and when the time of cooking was varied, the following results were were obtained:

PRELIMINARY SERIES III.

Time variable; 1.8 to 1.85 per cent of H_2SO_4; 400 per cent of H_2O; 7.5 atmospheres.

Cook No.	Time of cook, minutes.	Per cent of total sugars.	Per cent of total sugars fermentable.	Alcohol yields.	
				Per cent of dry wood.	Gallons absolute per ton.
15	0	22.59	54.87	6.096	.....
16	0	22.70			
21 [1]	0	23.16			
18	15	22.85			
17	30	22.95			

[1] Cook 21 had 300 per cent water instead of 400 per cent.

SERIES III.

Time variable; 2.50 per cent of H_2SO_4; 125 per cent of H_2O_2; 7.5 atmospheres.

Cook No.	Time of cook, minutes.	Per cent of total sugars.	Per cent of total sugars fermentable.	Alcohol yields.	
				Per cent of dry wood.	Gallons absolute per ton.
31	0	21.45	63.66	6.859	20.75
45	0	22.77	62.65	6.994	21.15
Average	0	22.11	63.16	6.927	20.95
32	10	21.32	69.79	7.339	22.20
47	10	23.40	67.27	7.984	24.15
Average	10	22.36	68.53	7.662	23.18
46	20	23.61	71.44	8.537	25.82
56	45	21.56	77.15	8.295	25.09
55	90	18.06	81.40	7.387	22.34

SERIES IIIa.

1.4 per cent of H_2SO_4; 125 per cent of H_2O; 7.5 atmospheres.

Cook No.	Time of cook, minutes.	Per cent of total sugars.	Per cent of total sugars fermentable.	Alcohol yields.	
				Per cent of dry wood.	Gallons absolute per ton.
33	0	23.17	54.20	6.972	21.09
40	0	23.74	53.67	6.319	19.11
39 [1]	0	22.37	53.92	6.214	18.80
Average	0	23.46	53.94	6.646	20.10
24	10	23.81	53.16	6.362	19.24
41	10	23.09	56.99	6.550	19.81
Average	10	23.45	55.08	6.456	19.53
42	30	22.34	63.22	6.862	20.76

[1] Blow-off open, not averaged.

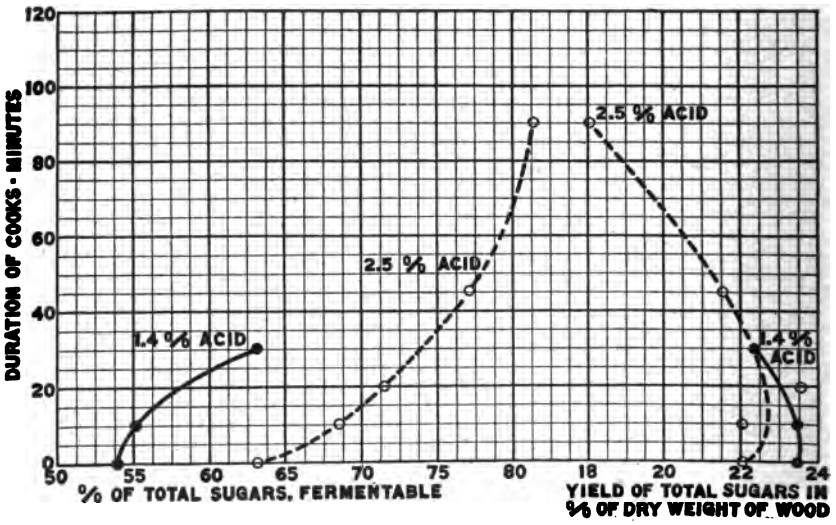


FIG. 3.—Series III and IIIa, showing the variation in yield of total sugars and percentage of total sugars that is fermentable with varying cooking periods at two different acid concentrations. Cooking pressure, 7.5 atmospheres.

These results are further illustrated graphically in figures 3, 4, and 5.

In a previous publication,[40] based on preliminary series III, the author stated that the time of cooking was apparently without effect. This statement was based on a total sugar data only, as practically all other alcohol data up to that time had been, and must now be, modified.

Altogether three concentrations of acid and two concentrations of water were used, except in cook 21, as noted in the table. For

[40] Jour. of Ind. and Eng. Chem. 1914, 625.

the instantaneous cooks no great difference in total sugars will be noted. Figure 3, series III*a*, shows a gradual decrease in the 1.4 per cent acid series, and a slight increase followed by a decrease in the 2.5 per cent acid series in total sugar yields; whereas figure 4, preliminary series III, shows practically no difference in a 0, 15, or 30 minute period. As shown in figure 3, however, decided increases were attained in the portion of total sugars which is fermentable, with increased alcohol yields (fig. 5), especially in the 2.5 per cent acid series. In this series the maximum yield was 8.54 per cent of alcohol, after which the yield dropped, although the yield of fermentable sugars kept on increasing. The total sugar yield, however,

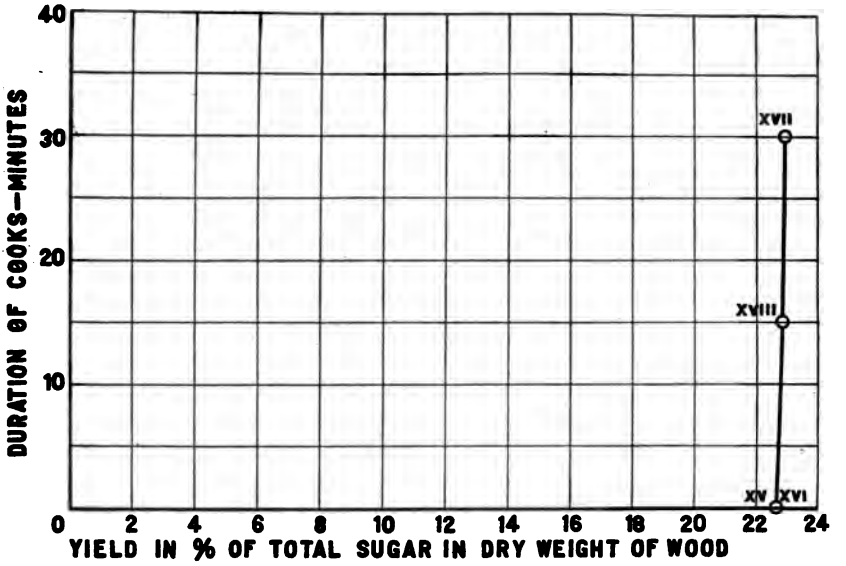


FIG. 4.—Preliminary series III, showing the variations in yield of total sugars with varying periods of cooking. Cooking pressure, 7.5 atmospheres.

decreased at a greater rate than the above increase, and gave lower alcohol yields.

Here again the data would permit of only doubtful interpretation or would lead to erroneous conclusions if only the total sugars were taken into account. The explanation of these results will be taken up later.

RATIO OF WATER TO WOOD.

All of the preliminary cooks were made with 400 per cent of water—that is, four times the dry weight of wood. This was the water ratio used by Simonsen, although that given in United States Patent No. 938308 by Ewen and Tomlinson was somewhat less than 4 to 1.

From an operating standpoint the reduction of the amount of water used is greatly to be desired. The reasons for this are: First,

the steam consumption in cooking is greatly decreased. Second, there is difficulty in obtaining a juice sufficiently concentrated to ferment and distill economically, because, if an excess of liquor is present in the digester, a large portion of the sugar is dissolved therein. Third, there is difficulty in handling a dripping, digested sawdust from which the acid liquor must be separated. The following table shows the results obtained by decreasing the ratio of 4 parts of water to 1 of dry wood down to equal parts of each.

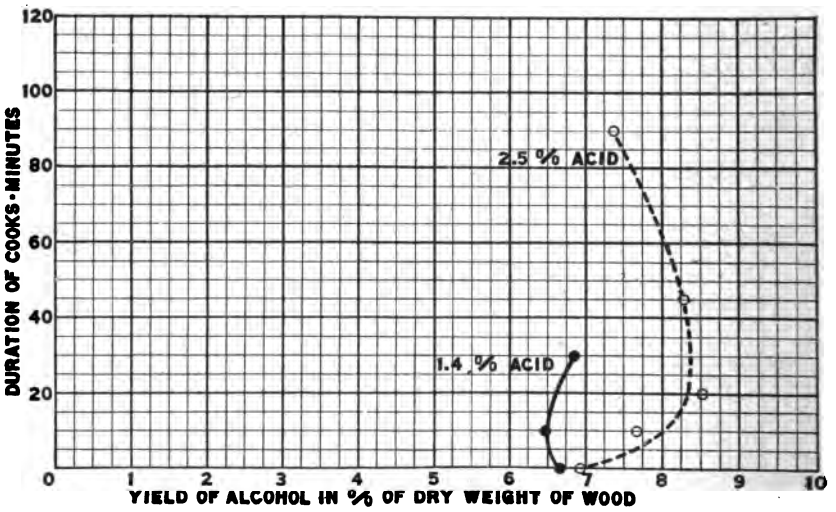


FIG. 5.—Series III and IIIa, showing variation in alcohol with varying cooking periods at two different acid concentrations. Cooking pressure, 7.5 atmospheres.

SERIES IV.

Water to wood ratio variable; 1.80 to 1.83 per cent of H_2SO_4; 7.5 atmospheres; 0 minute.

Cook No.	Per cent H_2O.	Per cent of total sugars.	Per cent of total sugars fermentable.	Alcohol yields.	
				Per cent of dry wood.	Gallons absolute per ton.
26	400	22.24	56.19	6.154	18.61
21	300	23.16	54.87	6.096	18.44
22	250	23.75	55.31	6.648	20.11
34	125	21.96	59.29	6.805	20.58
30	100	21.09	60.68	6.440	19.48

SERIES IV*a*.

1.40 per cent of H_2SO_4; 7.5 atmospheres; 0 minute.

Cook No.	Per cent H_2O.	Per cent of total sugars.	Per cent of total sugars fermentable.	Alcohol yields.	
				Per cent of dry wood.	Gallons absolute per ton.
43	200	21.84	57.94	6.369	19.62
44	100	23.00	57.16	6.665	20.16

In the experiments of series IV, 1.80 per cent of sulphuric acid was used. The experiments were then repeated with the use of 100 and 200 per cent of water with 1.40 per cent of sulphuric acid, and the results were the same. These results are shown graphically in

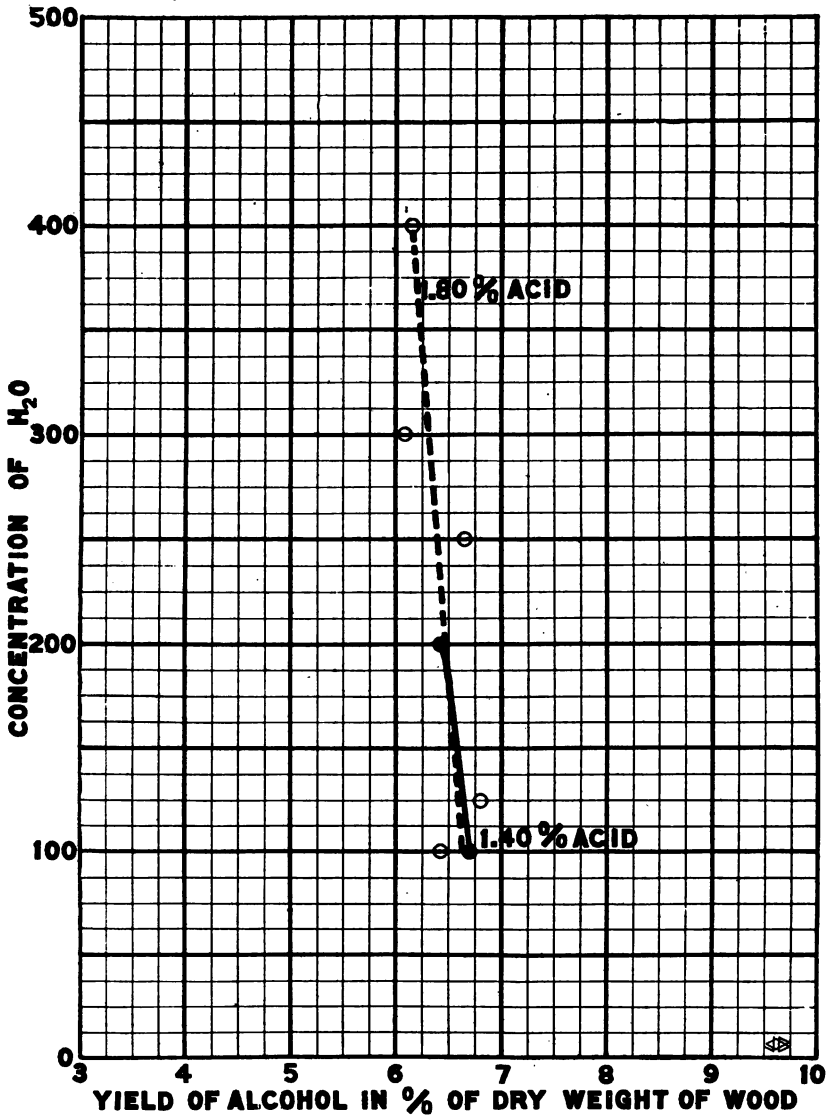


FIG. 6.—Series IV and IVa, showing variation in alcohol yields with varying concentrations of water at two different acid concentrations.

figures 6 and 7. Figure 6 shows that the average alcohol yields were very nearly constant for the different concentrations of water used, and figure 7 shows that this also held true for both the amounts of total sugars and the percentages of sugars that were fermentable.

There was a little more variation in the latter figures than in the alcohol values, because in the sugar data there was apparently a combination of variables in opposite directions. The 1.80 per cent

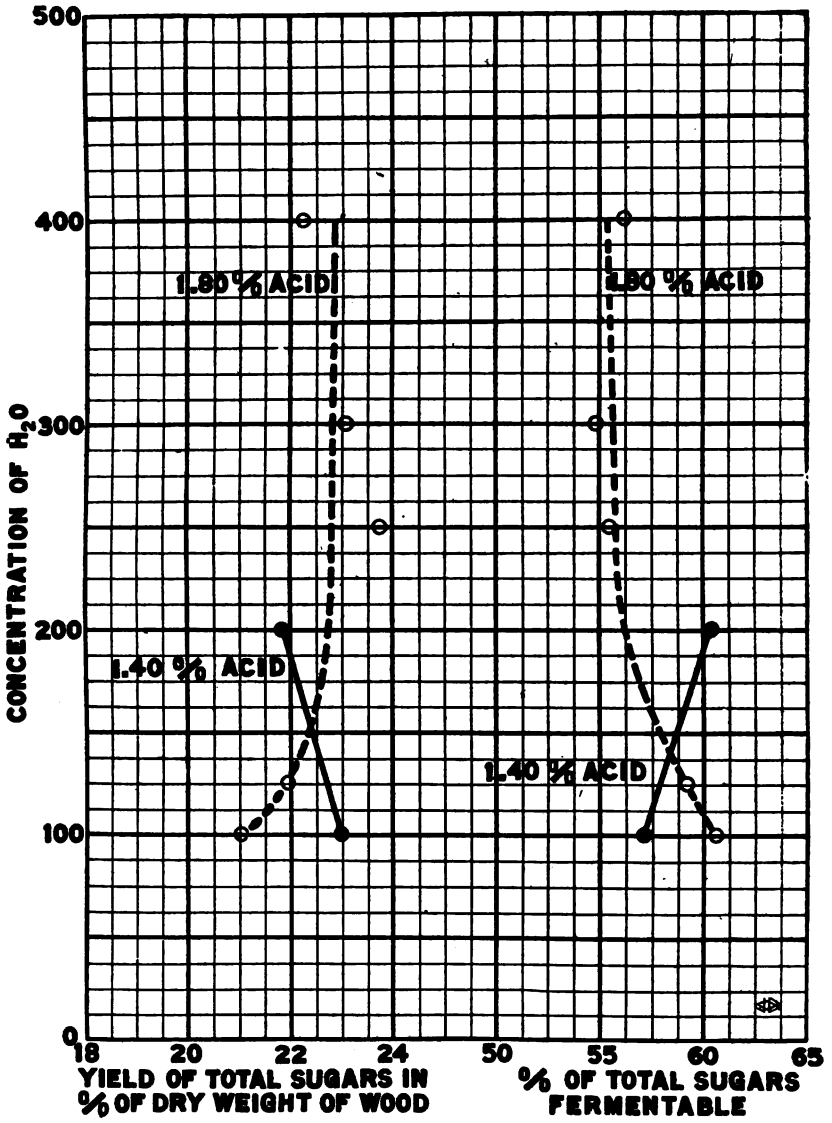


FIG. 7.—Series IV and IVa, showing variations in yield of total sugars and percentage of total sugars fermentable with varying concentrations of water at two different acid concentrations.

acid curves show that there was a slight decrease in total sugars with decreasing amounts of water; but the percentage of fermentable sugars increased at the same time, with the result that the actual alcohol yield was practically constant. A larger number of cooks

would probably have reduced these variations, but they were not deemed necessary to establish the principle involved.

Although 100 per cent of water gave results practically as good as did larger amounts, the operating conditions chosen for future work was 125 per cent of water. This was done for two reasons: First, to insure a better mixture of the acid in the wood, which, of course, is easier to accomplish with larger amounts of water, and, second, to use the maximum amount of water possible and still obtain a digested sawdust that has no drip. The advantages from the use of 125 per cent of water were felt to outweigh the small increase in steam consumption and to justify its adoption for future work. From calculations that have been made to determine the steam load on a commercial digester it was found that it takes 1,816,000 B. t. u. to a cook for heating the wood and acid solution, and 1,183,000 B. t. u. to heat the digester—a total of 2,999,000 B. t. u. to a cook. Decreasing the ratio of water to wood from 125 per cent to 100 per cent would decrease the total steam load to 2,709,000 B. t. u., a difference of 290,000, or about 10 per cent. The digester load, however, is only 25 to 30 per cent of the total steam load of the plant; consequently, the above would make a difference of only 2 or 2.5 per cent of the total steam load of the plant.

RATIO OF ACID TO WOOD.

The above ratio of water to wood (125 per cent) and a 0-minute cooking period were the constants used in the next series, in which the ratio of acid to wood was the variable. Sulphuric acid was used as the catalytic agent and in amounts varying from 0.5 per cent to 4 per cent of the dry weight of the wood. The results are given in the following table:

SERIES V.

125 per cent of H_2O; 7.5 atmospheres; 0 minute.

Cook No.	Per cent H_2SO_4.	Per cent of total sugars.	Per cent of total sugars fermentable.	Alcohol yields.	
				Per cent of dry wood.	Gallons absolute per ton.
38	0.5	17.42	43.13	4.172	12.62
37	.75	21.83	56.03	6.085	18.41
35	1.00	21.68	56.43	6.506	19.68
33	1.40	23.17	54.20	6.972	21.09
40	1.40	23.74	53.67	6.319	19.11
39 [1]	1.40	22.37	53.92	6.214	18.80
Average	1.40	23.455	53.935	6.6455	20.10
34	1.80	21.96	59.29	6.805	20.58
30 [2]	1.80	21.09	60.68	6.440	19.48
31	2.50	21.45	63.66	6.859	19.75
45	2.50	22.77	62.65	6.994	21.15
Average	2.50	22.11	63.155	6.9265	20.95
36	4.00	21.10	66.63	7.000	21.17

[1] Blow-off open, not averaged. [2] 30 to 100 per cent H_2O, not averaged.

SERIES V*a*.—*Shortleaf pine.*

125 per cent of H_2O; 7.5 atmospheres; 10 minutes.

Cook No.	Per cent H_2SO_4.	Per cent of total sugars.	Per cent of total sugars fermentable.	Alcohol yields.	
				Per cent of dry wood.	Gallons absolute per ton.
48	2.50	17.15	60.27	5.201	15.73
49	4.00	14.02	66.59	4.262	12.89

The results of series V and V*a* for both spruce and shortleaf pine are shown graphically in figures 8 and 9. Figure 8 shows the actual alcohol yield based on the dry weight of the wood, and figure 9 gives

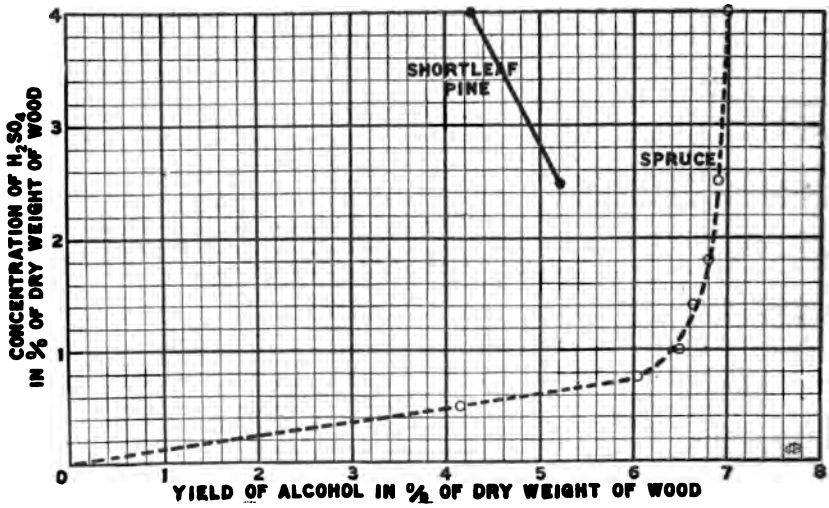


FIG. 8.—Series V and Va, showing variation in alcohol yield with varying concentrations of sulphuric acid for spruce and shortleaf pine.

the variations in total sugars and the portion of total sugars that is fermentable.

Figure 8 shows that the yield of alcohol from spruce increased rapidly with the lower concentrations of acid, but that above 1 per cent of acid the increase was comparatively small, there being little difference between 1 per cent and 3.5 per cent of acid. There was an actual decrease in the alcohol yield from shortleaf pine. This was because of the decrease of total sugars (fig. 9), although the amount of sugars fermentable increased from 60.29 per cent to 66.59 per cent of the total. The shortleaf pine used was a mixture of band sawdust and hogged slabs and edgings containing about 8 per cent of cypress and a considerable quantity of bark.

Even from spruce a decrease in total sugars is noticeable with acidities above 1.4 per cent, but here again the percentage of the total

fermentable sugars increases. As a result the total yield is not appreciably lessened and the alcohol yield remains practically constant.

In this series is seen again the importance of complete data; that is, data on total sugars, percentage of total sugars fermentable, and alcohol yields. All of these are necessary for a proper interpretation of the results, especially in an experiment like this, in which there is an apparent neutralization of two factors that vary in different ways.

A study of these two variables—namely, the ratio of water to wood and of acid to wood—shows that they are not mutually dependent,

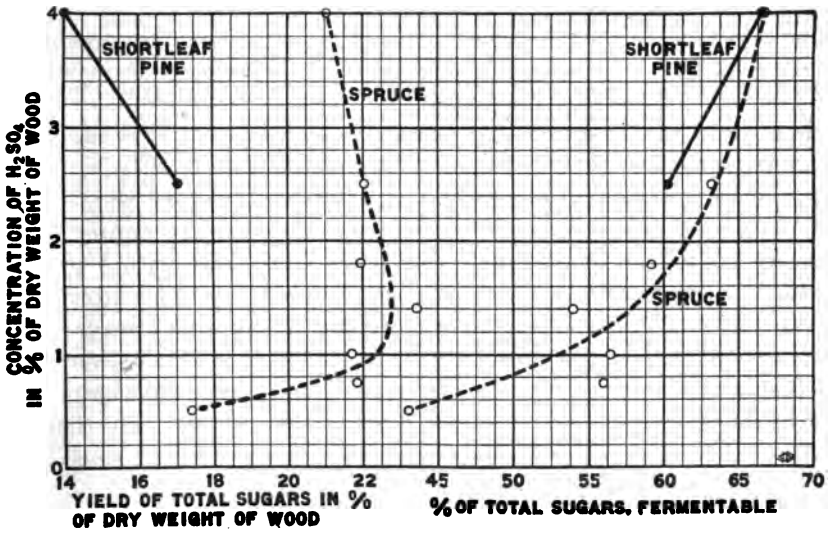


FIG. 9.—Series V and Va, showing variation in yields of total sugar and percentage of total sugars that is fermentable with varying concentrations of sulphuric acid for spruce and shortleaf pine.

that the acidity of the solution used for hydrolysis is of minor or no importance, but that the concentration of the catalytic agent expressed in percentage of dry wood is the decisive factor. As stated previously, Simonsen expressed all of his results in total sugar. When such long cooking periods are used (two hours in his work on variable No. 3—the influence of the amount of water present and of the acid concentration), it is not surprising that he found variable sugar yields with a constant amount of acid and varying amounts of water, or varying "acidities," as he called them. The decomposition products so obtained would be largely reducing agents, formic and lævulinic acids, which would show high sugar yields. Practically always, especially in the above work on cellulose, Simonsen used amounts of water which were technically not feasible. Neuman realized the technical importance of decreasing the ratio of water to wood, but carried it no further than 3 to 1—300 per cent of water.

He inverted 50 grams of air-dry sawdust with 150 c. c. of 0.5 per cent sulphuric acid (equivalent to 1.5 per cent of sulphuric acid based on air-dry wood) for one-half hour at 175° C., with 112 pounds of pressure to the square inch, and duplicate experiments showed yields of 20.4 and 20 per cent of total sugars. The percentages of total sugars fermentable and the alcohol yields were not given. In the discussion of his results he gives the following:

> These experiments prove that one can work with small amounts of liquid without exerting a deleterious action on the yields. In fact, the yields in experiments 63 and 64 (the two referred to above) are higher than in former ones in which larger amounts of liquids were used. At the same time, the extracts contained a greater percentage of sugar which is also favorable for fermentation. On the contrary, a small amount of liquid (acid solution) is not advisable, since in another experiment with sawdust and 2 parts of liquid (0.5 per cent sulphuric acid) at 175° C. a considerable evolution of sulphur dioxide took place with partial cooking of the materials used.

It must be remembered that the above experiments were made on 50-gram samples of wood heated in an autoclave indirectly; whereas the results obtained at the Forest Products Laboratory were based on 100-pound samples cooked with steam. At the laboratory there was no coking in instantaneous or short-time cooks with 1 part of water to 1 of wood; although, with the higher acid concentrations, irrespective of the amount of water used, there was always some coking—that is, a darkening of the digested wood. When Neumann used sulphuric acid as the catalytic agent, he nearly always employed a 0.5 per cent solution and simply varied the amount. He thereby confused the effect of his ratios of water and acid to wood, since they were both varied simultaneously.

If steam was used as the heating agent, of course some further dilution occurred during cooking; the more water used to begin with, the greater was this dilution. In an experimental apparatus, like that used at the Forest Products Laboratory, the amount of steam required to heat the digester was greater in proportion to the amount necessary to heat the wood and acid solution than it would be in a large commercial digester holding two or more cords of wood. The following data from cooks Nos. 30 and 34 show in general how much this dilution was:

	Cook 30, June 30, 1914.	Cook 34, July 29, 1914.
Water ..... per cent	100.	125.
H_2SO_4 ..... do	1.80	1.80.
Minutes	0.	0.
Atmospheres	7.5.	7.5.
Blow-off (condensed) ..... pounds	38.48.	41.41.
Digested sawdust ..... do	271.20.	288.06.
Dry wood ..... do	103.55.	100.68.
Water added ..... do	103.5.	126.
Excess water in digested sawdust over amount added ..... do	64.10.	61.38.
Ratio of water to wood in digested sawdust	1.62 to 1.	1.86 to 1.

In cook No. 30, with an original ratio of water to wood equal to 1 to 1, the ratio increased to 1.62 to 1, an increase of 62 per cent. In cook No. 34, with an original ratio of 1.25 to 1, the ratio increased to 1.86 to 1, an increased of 61 per cent, which was practically identical with that of cook No. 30. In both cooks the yields of total sugars, percentages of total sugars fermentable, and yields of alcohol were practically identical, as shown in the table of results on series IV, page 36. It seems, therefore, that if there is sufficient water to insure a good mixture of the catalytic agent with the wood, both the water and acidity of the solution added are without effect; and that, of these two variables, the only one affecting the yields is the concentration of the catalytic agent based on the amount of dry wood present.

Increasing the concentration of the catalytic agent caused increased yields of total sugars up to about 1.5 per cent of sulphuric acid; then the yields begin to decrease, although the portion of the sugars that is fermentable increased without a break in the curve. The increase in the amount of sugars fermentable is sufficient to offset the decrease in total sugars, and consequently the resulting alcohol yield is practically constant. The explanation of this condition, as shown on pages 30 to 33, is that the nonfermentable sugars (the pentoses) are the more unstable under the conditions used, and pentose decomposition takes place with increasing amounts of the catalytic agent. This pentose decomposition accounts for a decrease of the total sugar yield and an increase of the fermentable sugars, especially if there is little or no hexose decomposition; and the result is a practically constant alcohol yield similar to that obtained. As in the inversion of cane sugar in the presence of an acid, here also the speed of the reaction is probably determined by a combination of the catalytic effects of both the hydrogen ions and the non-ionized acid; moreover, the increased amounts of sugar formed with increased acid concentration may in part be a result of the non-ionized molecule. However, this is not the full explanation of the conditions observed. If it were, the 4 per cent acid series should give yields as much greater than those of the 2.5 per cent acid as the 2.5 per cent acid yields are greater than those of the 1 per cent; but this is not the case.

The above discussion has been limited entirely to the results of the experiments on spruce. Only two cooks were made on shortleaf pine, and these were insufficient to warrant any conclusions, especially in view of the complex nature of the raw material.

SIZE OF CHIPS.

Two cooks were made on chips of two different sizes and under the conditions outlined in the table below.

125 per cent of H_2O; 2.5 per cent of H_2SO_4; 7.5 atmospheres; 15 minutes.

Cook No.	Length of chip with the grain (inches).	Per cent of total sugars.	Per cent of total sugars fermentable.	Alcohol yields.	
				Per cent of dry wood.	Gallons absolute per ton.
59	½ to $\frac{1}{16}$	20.21	73.50	7.126	21.55
60	⅜	21.005	69.07	7.214	21.82
61	Mixture.	20.14	71.16	7.109	21.50

Even the larger chips were thoroughly penetrated and cooked, and the yield obtained from them compares favorably with that obtained from sawdust under similar conditions. The chips, however, did not extract readily, and while they were being stirred in the leaching tank they were ground to a powder. In a commercial diffusion battery there would not, of course, be a similar mechanical action, but the time of extraction and the capacity of the battery would be decreased. A lack of material prevented leaching experiments, and these results were obtained primarily to determine whether material of this size would give yields similar to those from sawdust. Further work along this line is necessary.

Cook No. 61 was a mixture of sawdust, small chips, and large chips in the following amounts:

	Moisture.	Air-dry weight.	Dry weight.
	Per cent.	*Pounds.*	*Pounds.*
Sawdust	8.78	31.35	28.60
Large chips	9.67	46.96	42.41
Small chips	9.37	41.04	37.20

This mixture was cooked at 7.5 atmospheres with 125 per cent of water and 2.5 per cent of sulphuric acid for 15 minutes. After it was cooked, a sample of the mixture was taken and extracted and the extract analyzed in the usual way. Another part of the sample was screened through a screen having openings three-eighths of an inch square, and the materials passing through the screen and remaining on it were also extracted and analyzed in the usual way. The following table shows the results of these analyses:

Digested mixture.	Moisture (per cent).	Total sugars, (per cent of wet weight).	Total solids (per cent of wet weight).	Acidity of extract (C. c. N/10 NaOH).
Unscreened	70.26	6.616	7.196	7.5
Remaining on ⅜-inch screen	70.54	6.853	7.28	7.6
Passing through ⅜-inch screen	71.11	6.688	7.32	7.6

LEACHING TANK, *L*; SETTLING TANKS, S_1 AND S_2; SINGLE-EFFECT VACUUM EVAPORATOR, *E*; HYDRO-EXTRACTOR, *H*.

EVAPORATOR *E*, CONNECTED TO SURFACE CONDENSER *D*, AND DRY VACUUM PUMP *F*. CORNER OF FERMENTATION ROOM BUILT IN UPPER CORNER OF LABORATORY BEYOND EVAPORATOR AND CONDENSER.

From these figures it will be seen that all the material was equally cooked and gave practically the same yields, irrespective of size within the limits used. In addition, the material leached readily without formation of fine stuff, and 88.4 per cent of the sugar present was extracted without difficulty in three leachings. A certain amount of sawdust or material of similar size, therefore, seems necessary in order to obtain a good extraction, even though chips as large as five-eighths of an inch with the grain may be cooked under the conditions outlined in as short a time as 15 minutes and with good yields.

It has been observed in commercial practice that a mixture of dust and chips in the proportion of 10 to 15 per cent of dust and 90 to 85 per cent of chips gives the best results in the diffusion battery. If all dust or too much dust is used, the cooked material packs in the cells, high pressures are required to force the extracting water through it, and the material hangs in the cells at the time of discharge, causing loss of time in operation. If dust-free chips are used, the opposite is true; the extracting water percolates too fast, and extraction is not good. With the proper combination of dust and shredded chips, a 92 per cent extraction of the total sugar may be obtained.

LEACHING EXPERIMENTS.

The determination of the number of cells in a diffusion battery necessary to get a maximum extraction in a minimum time, with a minimum amount of water, is a very important point in this process. Furthermore, it was desirable to determine whether there was any selective solubility between the different sugars present or the soluble solids other than sugars. With this end in view, two series of cooks were made under the same conditions, viz, 125 per cent of water, 2.5 per cent of sulphuric acid, a pressure of 7.5 atmospheres, and a cooking period of 15 minutes. It is regrettable that an accident to some of the condensing apparatus prevented blowing off these cooks, and after each cook it was necessary to allow the digester to cool gradually to 212° F. or less before the contents were discharged. Undoubtedly reducing substances were formed and retained which were the cause of erratic sugar data being obtained.

Cooks Nos. 51 and 52 were preliminary and were made for the purpose of outlining a method of procedure. The digested sawdust from both cooks was put into the leaching tanks and successively leached by sprinkling small quantities of boiling water over the digested sawdust and collecting the drip as soon as it had drained through the sawdust. The different extracts were then analyzed, neutralized, and fermented in the usual manner with the following results.

COOKS NOS. 53 AND 54.

Leach No.	Fermentation No.	Neutral juice before fermentation.		Beer.			Per cent of total sugars fermentable.	Theoretical alcohol.	Fermentation efficiency.	Acidity.		
		Sp. gr. at 15° C.	Reducing sugars, (grams per liter).	Sp. gr. at 15° C.	Reducing sugars (grams per liter).	Alcohol (per cent by weight), (liter).				Neutral juice.	Beer.	Increase.
1	10	1.0502	62.28	1.0262	17.40	1.910	71.40	2.164	88.26	6.2	12.0	5.8
	11	1.0508	61.70	1.0280	11.74	2.267	80.55	2.418	93.76	2.4	9.6	7.2
2	10	1.0482	61.56	1.0277	14.88	2.233	75.34	2.262	98.72	4.4	11.2	6.8
	11	1.0509	66.04	1.0270	14.74	2.313	77.16	2.478	93.34	4.4	10.4	6.0
3	10	1.0492	59.52	1.0273	17.08	2.171	70.68	2.050	105.90	6.4	12.5	6.1
	11	1.0480	60.24	1.0269	16.00	2.152	72.89	2.142	100.47	6.0	11.2	5.2
4	10	1.0486	62.12	1.0286	18.52	2.129	69.62	2.108	101.00	3.6	11.4	7.8
	11	1.0521	68.70	1.0296	18.88	2.360	71.91	2.400	98.33	4.0	9.6	5.6
5	10	1.0488	57.28	1.0304	17.86	1.844	68.26	1.905	96.80	2.4	10.4	8.0
	11	1.0532	62.28	1.0338	18.92	1.949	69.05	2.087	93.39	3.8	10.0	6.2

Cooks Nos. 53 and 54 were combined and handled in the same way; but not until previous experiments had indicated the quantities of water necessary to leach out approximately equal quantities of sugar. In all, nine leaches were made, although only the drip and the first eight leaches contained enough sugar to make a fermentation possible. The following table shows the amounts of water added for each leach, the amounts of extract recovered, the sugars and total solids in each extract, and the percentages of total sugars fermentable, with the fermentation efficiencies:

COOKS NOS. 53 AND 54.

Leach No.	Amount of water added.		Amount of extract recovered (pounds).	Sp. gr. of extract at 15° C.	Reducing sugars (grams per liter).	Weight of sugars in extract (pounds).	Total solids (per cent).	Total solids in extract, (pounds).	Ratio of sugars to total solids (per cent).	Acidity (c. c. N/10 NaOH per 100 c. c.).
	Liters.	Pounds.								
Drip	.....	.....	83.29	1.0482	74.54	5.93	8.187	6.72	88.3	73.4
1	20	44.0	38.39	1.0518	80.12	2.92	8.897	3.41	85.7	75.0
2	30	66.1	61.70	1.0522	79.48	4.66	8.866	5.47	85.3	74.5
3	30	66.1	63.76	1.0501	78.48	4.77	8.195	5.22	91.4	76.8
4	30	66.1	71.32	1.0504	75.36	5.12	8.180	5.83	87.9	74.6
5	50	110.2	94.21	1.0443	65.75	5.94	7.314	6.90	86.1	74.0
6	75	165.3	160.93	1.0360	50.08	7.77	5.757	9.27	83.4	63.0
7	100	220.5	194.21	1.0258	34.29	6.51	4.188	8.14	81.9	45.1
8	300	661.4	647.14	1.0109	14.00	8.96	2.198	14.21	63.1	18.9
9	500	1,102.3	997.94	1.0015	1.66	1.655	0.220	2.19	75.6	2.1

COOKS NOS. 53 AND 54—Continued.

Leach No.	Fermentation No.	Neutral juice before fermentation.		Beer.			Per cent of total sugars fermentable.	Theoretical alcohol.	Fermentation efficiency.	Acidity.		
		Sp. gr. at 15° C.	Reducing sugars (grams per liter).	Sp. gr. at 15° C.	Reducing sugars (grams per liter).	Alcohol (per cent by weight).				Neutral juice.	Beer.	Increase.
Drip	12	1.0515	62.38	1.0337	23.52	1.625	61.65	1.869	86.94	3.9	12.0	8.1
	13	1.0506	61.92	1.0284	10.84	2.188	82.12	2.474	88.44	8.0	13.2	5.2
1	12	1.0497	62.12	1.0422	44.70	0.648	27.51	0.832	77.88	3.8	7.0	4.8
	13	1.0460	55.12	1.0367	33.86	0.897	38.03	1.024	87.60	6.8	8.0	1.2
2	12	1.0473	57.08	1.0298	18.72	1.690	66.64	1.856	91.06	3.6	10.8	7.2
	13	1.0510	63.92	1.0284	11.74	2.266	81.22	2.525	89.74	9.4	12.4	3.0
3	12	1.0495	59.52	1.0275	10.04	2.087	82.77	2.399	86.99	3.7	12.1	8.4
	13	1.0520	61.96	1.0401	35.30	1.019	42.38	1.276	79.86	8.8	11.8	3.0
4	12	1.0508	57.74	1.0287	10.68	2.090	81.11	2.278	91.75	4.3	12.8	8.5
	13	1.0502	57.34	1.0299	12.36	1.913	78.02	2.177	87.87	9.2	12.4	3.2
5	12	1.0515	54.76	1.0321	13.12	1.836	75.60	2.012	91.25	3.9	12.9	9.0
	13	1.0538	58.34	1.0475	41.16	0.549	29.03	0.824	66.87	8.6	11.4	2.8
	14	1.0504	53.22	1.0329	15.24	1.646	70.89	1.836	89.65	8.0	12.4	4.4
6	12	1.0456	52.52	1.0343	7.84	2.016	84.91	2.180	92.48	3.3	12.2	8.9
	13	1.0490	47.38	1.0308	8.14	1.790	82.51	1.905	93.96	4.4	11.0	6.6
	14	1.0515	49.56	1.0324	8.28	1.951	82.92	1.999	97.60	6.0	10.0	4.0
7	12	1.0576	53.04	1.0371	8.48	1.851	83.69	2.145	86.29	4.1	12.4	8.3
	13	1.0496	46.19	1.0326	8.00	1.724	82.39	1.853	93.03	3.8	11.2	7.4
	14	1.0481	43.76	1.0314	7.78	1.682	81.94	1.748	96.22	6.4	11.0	4.6
8	12	1.0547	47.32	1.0380	9.00	1.772	80.67	1.850	95.78	3.6	12.0	8.4
	13	1.0519	44.14	1.0357	8.52	1.685	80.39	1.724	97.74	6.6	10.8	4.2
	14	1.0489	42.46	1.0338	7.56	1.610	81.94	1.695	94.98	6.4	12.0	5.6
9[1]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

[1] Insufficient sugar for fermentation.

A considerable amount of variation will be noted in the percentages of total sugars fermentable, although all of the extracts, excepting Nos. 1 and 5, have at least one fermentation with over 80 per cent of the total sugars fermentable. Extract No. 5 shows one fermentation with 75.60 per cent of sugars fermentable, but both fermentations of extract No. 1 are very low. The latter is only 2.72 per cent of the total weight of extract obtained, but contains 5.40 per cent of the total sugar calculated as dextrose. Apparently we have here some strongly reducing substances present which are very soluble, which react as a sugar toward Fehling's solution, but which do not ferment. This material was also extracted in a greater or less quantity in the succeeding leaches up to and including No. 5, and it was, therefore, difficult for the yeast to get control and furnish a good fermentation. Not until the beginning of the sixth leach were fairly uniform and constant fermentations obtained.

From the foregoing results it is apparent that the sugars should be extracted as completely as possible, as the last extracts are apparently the purest from a fermentation standpoint. This work should be repeated, however, for additional data are necessary before final judgment is passed on a phase of the work of so great technica importance. The data given are indicative but insufficient to be conclusive in this respect.

Commercially, the subject of extraction, covering the questions of size, design, and number of cells in a diffusion battery, is one that has received a great deal of attention in the beet-sugar industry. In the light of data obtained in units of commercial size in the ethyl-alcohol industry, it may be said that at least a 5-cell draw—that is, passing the extracting medium through 5 cells in rotation—is necessary, and that a 6 or 7 cell draw is more desirable. The amount of water to be used and the proper end point or time of drawing must be determined for each particular battery, and with proper care and supervision the efficiency of the entire operation can be maintained at a 92 per cent extraction with a 10° to 11° Brix acid juice corrected for temperature.

VOLATILE ACID YIELDS.

In addition to the sugars obtained as hydrolytic products, acetic and formic acids were also obtained in varying amounts. The yields are given on the acid-yield sheet in the Appendix, in addition to the following tables, in which the cooks have been outlined in the different series as given before under pressure, time, water to wood and acid to wood ratios:

SERIES I*b*.

PRESSURE VARIABLE.

1.80 per cent of H_2SO_4; 400 per cent of H_2O (water); 0 minute.

Cook No.	Pressure.	Yield of volatile acid (per cent of dry weight of wood).		
		Acetic.	Formic.	Both.
20	6.5	1.25	0.105	1.355
15	7.5	1.22	.185	1.405
16	7.5	1.62	.220	1.840
19	9.0	1.60	.443	2.043

SERIES III.

TIME VARIABLE.

2.5 per cent of H_2SO_4; 125 per cent of H_2O; 7.5 atmospheres.

Cook No.	Time of cook (minutes).	Yield of volatile acid (per cent of dry weight of wood).		
		Acetic.	Formic.	Both.
31	0	1.755	0.572	2.827
45	0	1.670	.790	2.460
32	10	1.67	1.090	2.760
47	10	2.62	.340	2.96
46	20	2.360	1.450	3.81
56	45	2.915	1.492	4.407
55	90	2.140	.440	2.580

Series III*a*.

TIME VARIABLE.

1.4 per cent of H_2SO_4; 125 per cent of H_2O; 7.5 atmospheres.

Cook No.	Time of cook (minutes).	Yield of volatile acid (per cent of dry weight of wood).		
		Acetic.	Formic.	Both.
33	0	1.457	0.355	1.812
40	0	1.560	.470	2.030
24	10	2.39	.059	2.449
41	10	1.416	.430	1.846
42	30	1.55	.570	2.120

Preliminary Series III.

TIME VARIABLE.

1.80 per cent of H_2SO_4; 400 per cent of H_2O; 7.5 atmospheres.

Cook No.	Time of cook (minutes).	Yield of volatile acid (per cent of dry weight of wood).		
		Acetic.	Formic.	Both.
15	0	1.22	0.185	1.405
16	0	1.62	.220	1.840
18	15	1.32	.598	1.918
17	30	1.48	.570	2.050

Series IV.

WATER TO WOOD RATIO.

1.80 to 1.83 per cent of H_2SO_4; 7.5 atmospheres; 0 minute.

Cook No.	Per cent of water.	Yield of volatile acid (per cent of dry weight of wood).		
		Acetic.	Formic.	Both.
26	400	1.75	0.431	2.181
21	300	1.52	.239	1.759
22	250	(1)	(1)	(1)
34	125	2.11	.480	2.590
30	100	1.38	.642	2.022

[1] Data not complete.

Series IV*a*.

WATER TO WOOD RATIO.

1.40 per cent of H_2SO_4; 7.5 atmospheres; 0 minute.

Cook No.	Per cent of water.	Yield of volatile acid (per cent of dry weight of wood).		
		Acetic.	Formic.	Both.
43	200	1.51	0.160	1.660
44	100	1.69	.290	1.980

SERIES V.

ACID TO WOOD RATIO.

125 per cent of H_2O; 7.5 atmospheres; 0 minute.

Cook No.	Sulphuric acid (per cent of dry wood).	Yield of volatile acid (per cent of dry weight of wood).		
		Acetic.	Formic.	Both.
38	0.5	0.87	0.430	1.30
37	.75	1.43	.253	1.683
35	1.00	1.05	.443	1.493
33	1.40	1.457	.355	1.812
40	1.40	1.56	470	2.030
34	1.80	2.11	.480	2.59
30	1.80	1.38	.642	2.022
31	2.50	1.755	.572	2.827
45	2.50	1.67	.790	2.460
36	4.00	2.43	.735	3.165

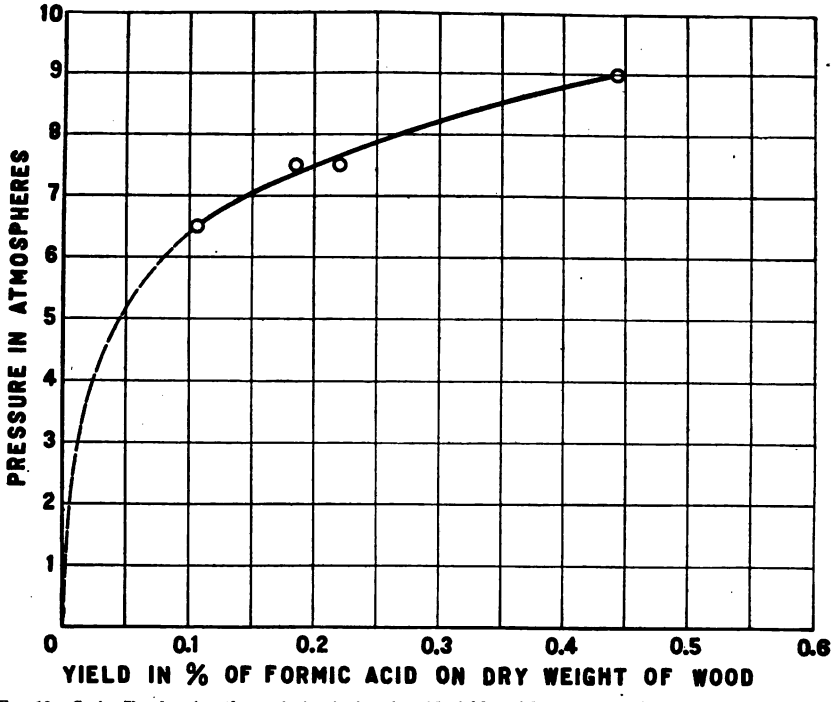


FIG. 10.—Series Ib, showing the variation in formic-acid yields, with varying cooking pressures. Cooking period, 0 minutes.

Both the yields of acetic and formic acid varied with the cooking conditions, although the former was the more constant of the two. The variations in the water to wood ratio in general seemed to be without effect on the yields of both acids, and this was to be expected. Increasing the pressure of cooking increased the amount of formic acid, particularly as shown in the curve for series *Ib* in figure 10, and this was apparently due in part to sugar decomposition. Increasing the

acidity based on the dry wood increased particularly the amount of formic acid produced, whereas increasing the time of cooking seemed to increase both acids, although the increase of formic acid was proportionately much greater than that of acetic acid.

The source of these acids at the temperatures used is apparently a hydrolysis of the acetyl and formyl groups present in the lignin complex, as suggested by Cross and Bevan[41] and by Cross,[42] who determined these acids as results of the acid hydrolysis of a number of materials. Bergström[43] also obtained these acids as a result of hydrolysis without the aid of an acid catalyst, with the use of water at 6 atmospheres of pressure. Formic acid, however, with lævulinic acid, carbon dioxide, etc., is a decomposition product of the sugars, and undoubtedly the large increases in formic acid yields with increased pressure, time of cooking, and concentration of catalyst are due to sugar decomposition. The data are of particular interest as furnishing an approximate index of the degree of this decomposition.

These acids in certain concentrations also have a toxic effect on yeast growth and no doubt inhibit fermentation to some extent, even in the neutralized juice in which the acids are present as their calcium salts. In addition, nearly the same amount of acid was obtained at the Forest Products Laboratory as is usually obtained by the destructive distillation of this species of wood, and in a few cases more. It is known that the rapid decomposition of wood does not begin till a temperature of 275° to 280° C.[44] is reached, after which the decomposition is exothermic. Since the formic acid is derived from the wood and also from sugar decomposition, the amount hydrolyzed from the wood directly is difficult to determine. If this amount were known, it would give a helpful index, similar to the methoxy number now used, of the value of a species of wood for certain purposes. It has been shown beyond question[45] that the destructive distillation of cellulose, sulphite, or soda wood pulp, as well as cotton, yields acetic acid, but no methyl alcohol, and Klason and his coworkers have obtained a yield of 2.79 per cent of acetic acid from spruce sulphite cellulose. More than this amount of acetic acid was obtained in cook No. 56 at the Forest Products Laboratory by hydrolysis of the wood at a temperature 100° C. lower.

In view of the work of Cross and Bergström, it seems that the greater part of the acetic and formic acids, with the exception of the formic acid that results from sugar decomposition, comes from the hydrolysis

[41] Cross and Bevan, Berichte, 28, 1940.

[42] Cross, W. E., Dissertation, Göttingen, 1910, Ueber das Vorkommen der Formyl- und Acetyl Gruppen im Lignin.

[43] Bergström, Der Papierfabrikant, 2, 305.

[44] Klason, P., Jour. für prakt. Chemie, 1914, 90, 413-447.

[45] Buttner, G., and Wislicenus, H., Jour. für prakt. Chemie, 79, 177-234; Klason, von Heidenstam, and Norlin, Zeit. für ang. Chemie, 1909, 1205.

of the acetyl and formyl groups in the lignin. Bergström obtained as much as 1.53 per cent acetic acid and 0.23 per cent of formic acid from spruce boiled in water at a pressure of 6 atmospheres for two hours without any catalyst, whereas cellulose produced from spruce yielded only 0.08 per cent of combined acids under similar treatment.

This being true, the maximum amount of acid obtainable from wood is the sum of the acid produced by the destructive distillation of the cellulose and the hydrolysis of the lignin. This would be 5.7 per cent total acid, which, so far as the writer's knowledge extends, has never been obtained by the destructive decomposition of wood. Undoubtedly secondary decomposition products are formed, such as $2CH_3COOH = (CH_3)_2CO$ plus H_2O plus CO_2, 2 HCHO plus $H_2O = CH_3OH$ plus HCOOH, and similar reactions, which may account for the acetone and in part for the formic acid obtained from destructive distillation.

A series of destructive distillations has been made at the Forest Products Laboratory on spruce and spruce-digester residues cooked with sulphuric acid for sugar and alcohol production. These distillations were made, some slowly and some quickly, some very wet and some very dry, to determine whether the hydrolytic effect noted above could be reproduced in the destructive-distillation process. The details of this work are being reserved for later publication; but it may be stated here that the distillation of either wet wood or wet residue produced more total acid than was obtained from the dry wood or dry residue under similar distillation conditions, showing that there was a hydrolytic effect from the added water. The increased amount of acid, however, was not sufficient to pay for its recovery from the more dilute pyroligneous acid produced.

Aside from the scientific interest of the subject and its bearing on the chemistry of wood, the technical importance of the recovery of these acids is to be considered. As outlined previously, this has been attempted in France and in the processes covered by the patents granted to Cohoe in this country. Cohoe, however, worked with broad-leaved woods, which would give even larger amounts of these acids. The table in the Appendix, however, shows that the amount of acid which might be recovered in the condensed blow-off averages only about 10 per cent of each, and this would yield a condensate of little value. As the average concentration of acetic acid in the condensed blow-off was only about 0.20 per cent, it is questionable whether recovery in commercial amounts is possible. If some means could be devised, however, for washing out the volatile acids with steam and making a practically complete recovery of them without too great expense or delay to the digester cycle, these acids might form a valuable by-product of this industry.

EFFECT OF TANNIN AND BARK.

Various mixtures of spruce and spruce bark were cooked under the usual conditions of 7.5 atmospheres of pressure, 125 per cent of water, and 2.5 per cent of sulphuric acid based on dry weight. The results are given in the following table:

	Cook No.	Total sugars (per cent of original dry weight).	Per cent of total sugars fermentable.	Alcohol yields.	
				Per cent of original dry weight.	Gallons absolute per dry ton.
All spruce wood	84	22.11	70.38	7.457	22.55
91.5 per cent of wood, 8.5 per cent of bark	87	19.60	69.47	6.765	20.46
74.5 per cent of wood, 25.5 per cent of bark	85	22.49	60.04	6.364	19.25
All bark	88	17.07	31.95	2.730	8.25

From the result it is seen that as much as 25 per cent of spruce bark may be mixed with the wood without appreciably decreasing the yield of alcohol. Other barks were not available in sufficient quantity to determine the practical limits to which they may occur in waste mixtures without appreciable effect. Commercial experience however, has shown that not more than 10 per cent of the total of yellow pine may be bark without seriously affecting the yield. Spruce bark has long been used in Europe as a tanning material and has found favor because of its high sugar content, which in the "mellowing" or fermentation and acidification of the tanning liquors produced a comparatively large amount of acid and was therefore used as a plumping agent.

The tannin present shows no inhibitory action toward yeast growth, for even sugar liquors produced from red and white oak gave normal fermentation and fermentation efficiencies. In commercial practice other factors have been found, such as long cooking periods with increased formations of acids, acetone, and aldehydes, which influence yeast growth and fermentation much more than does the tannin found in the sugar liquors usually produced from mill waste.

EFFECT OF CATALYZERS OTHER THAN SULPHURIC ACID OR IN ADDITION THERETO.

As indicated previously, Körner, Cohoe, and others have attempted the production of sugar and alcohol from wood with the use of hydrogen peroxide, potassium dichromate, and potassium persulphate as hydrating and oxidizing agents in addition to sulphuric acid, and these investigators have also recommended the use of hydrochloric acid. The experiments at the Forest Products Laboratory have been only preliminary to an investigation of the field, but they have confirmed several known facts besides establishing several new ones.

Theoretically, hydrochloric acid, because of its maximum ionization should produce even greater sugar yields than sulphuric acid. Hydrochloric acid presents greater technical difficulties than does sulphuric acid, and its cost is greater; however, if the yield were increased sufficiently, the other difficulties could probably be overcome. Two concentrations of hydrochloric acid were therefore tried, one of 1.80 per cent and another of 2.50 per cent, based on dry-wood weight, and the respective total sugar yields were 19.69 per cent and 17.02 per cent. The complete data on cooks Nos. 89 and 90 are given in the tables in the Appendix. That yeast is intolerant of the Cl ion is well known, and the laboratory workers were unable, as others before had been, to obtain any fermentations. Unless, therefore, the Cl ion is removed by precipitation, as with silver nitrate, fermentation is impossible. No fermentation was obtained when chlorine or chlorides were used. The chief interest of the following experiments, therefore, is in the data adduced with respect to total sugars, for, as stated before, if it were possible materially to increase the total sugars obtained, other difficulties might possibly be overcome.

Spruce.

7.5 atmospheres; 125 per cent of H_2O.

Cook No.	Catalyst.	Total reducing sugars (per cent of original dry wood).
93	1.8 per cent of hydrochloric acid	18.25
90	1.8 per cent of hydrochloric acid	19.69
89	2.5 per cent of hydrochloric acid	17.02
92	1.8 per cent of sulphuric acid plus salt (NaCl) for equation $H_2SO_4+NaCl=NaHSO_4+HCl$	20.44
94	1.8 per cent of sulphuric acid plus salt (NaCl) for equation $H_2SO_4+2\,NaCl=Na_2SO_4+2\,HCl$	19.44
95	2 per cent of chlorine from $2\,KClO_3+H_2SO_4+10\,HCl=K_2SO_4+6\,H_2O+6\,Cl_2$	19.59
96	1.8 per cent of sulphuric acid plus 10 per cent of $KClO_3$ to make $2\,KClO_3+H_2SO_4=K_2SO_4+2\,HClO_3$	20.34
97	1.8 per cent of sulphuric acid plus 50 per cent of $KClO_3$ to make $2\,KClO_3+H_2SO_4=K_2SO_4+2\,HClO_3$	21.45

The above table shows no yields of total sugars greater than it is possible to obtain with the use of sulphuric acid only. Even if all the sugars produced were fermentable and could be fermented, the yield would not justify the added expense. Simple chloride and chlorine treatments in their technical aspect may, therefore, be dismissed, although the results are of interest in their bearing on the chemistry of wood.

The next experiment was with the use of ferrous sulphate in conjunction with sulphuric acid—that is, with an increase in the concentration of sulphate ions. The result, especially when taken in connection with the experiments on niter cake described below, is of

sufficient interest and value to warrant further investigation. Reference should be made to all the data of cook No. 104, which was a standard cook using 1.8 per cent of sulphuric acid plus 0.1 per cent of ferrous sulphate. The results are given in the following table, along with data from cook No. 34, showing the results from the use of 1.8 per cent of acid without the addition of ferrous sulphate. Although the differences between the two cooks are small, the slight increase in fermentable sugar when the ferrous sulphate was used is worthy of consideration.

125 per cent of H_2O; 7.5 atmospheres.

Cook No.	Catalyst.	Total sugars.	Per cent of total sugars fermentable.	Alcohol yield.	
				Per cent of dry wood.	Gallons per ton.
34	1.8 per cent of H_2SO_4	21.96	59.29	6.805	20.58
104	1.8 per cent of H_2SO_4; 0.1 per cent of $FeSO_4$	21.40	63.23	6.927	20.97

Two cooks were made with niter cake furnished through the courtesy of the E. I. du Pont de Nemours Co. In cook No. 107, niter cake only was used, and the amount of it was equivalent to 1.8 per cent of concentrated acid. In other words, 5.55 pounds of cake are equal to 1 pound of 100 per cent acid. In cook No. 108 a mixture of 0.9 per cent of acid and niter cake equivalent to 0.9 per cent of acid, making a total of 1.8 per cent of acid, was used. The results follow:

Cook No.	Catalyst.	Total sugars.	Per cent of total sugars fermentable.	Alcohol yields.	
				Per cent of dry wood.	Gallons per ton.
107	Niter cake	17.93	60.13	5.583	16.89
108	0.5 niter cake, 0.5 H_2SO_4	19.25	59.18	5.077	15.38

When these results are compared with those obtained from the use of acid alone, it is found that niter cake will produce, either alone or when mixed with as high as 50 per cent of the usual acid concentration, 75 or 80 per cent of the yield obtained with sulphuric acid alone. These experiments suggest interesting possibilities, provided the niter cake can be obtained at an appreciable saving as compared with the cost of sulphuric acid.

Three cooks were made with the use of phosphoric acid (H_3PO_4) alone or in mixture with sulphiric acid, and the results were as follows:

Spruce.

7.5 atmospheres; 125 per cent H_2O.

Cook No.	Catalyst.	Total sugars (per cent of original dry wood.)	Per cent of total sugars fermentable.	Alcohol yields.	
				Per cent of original dry wood.	Gallons per ton.
100	1.8 per cent of sulphuric acid, 0.1 per cent of phosphoric acid.	21.12	64.32	7.726	23.24
101	0.9 per cent of H_2SO_4, 0.9 per cent of H_3PO_4.	20.83	55.20	5.635	19.62
102	1.8 per cent of H_3PO_4	19.38	51.58	5.130	15.69

The above results are even better than were to be expected, if the relative degrees of dissociation of the two acids are considered. The slight increase in yield of cook No. 100, containing 0.1 per cent of phosphoric acid in addition to 1.8 per cent of sulphuric acid, as compared with cook No. 34 (p. 55), containing 1.8 per cent of sulphuric acid only, is not sufficient when its cost is considered to warrant the commercial use of even small quantities of phosphoric acid. Phosphates, of course, are necessary for yeast growth; and if they are present in considerable quantities in the mash during fermentation they act as a yeast stimulant. It has not been found necessary, however, to add any great quantity of phosphates in order to secure satisfactory fermentation. A pound or two of ammonium phosphate or a pint of "sirupy" acid added to the starting yeast in the early stages of its propagation is sufficient to insure vigorous growth.

STUDY OF DIFFERENT SPECIES.

All the cooks in this series were made under the following conditions: 2.5 per cent of sulphuric acid; 125 per cent of water; 7.5 atmospheres of pressure; 20 minutes cooking period. The results obtained divide the different species into their natural botanical classifications, namely, the coniferous and broad-leaved species. Although not all species in each class were tested, authentic samples of enough species were used to demonstrate the value of most of those woods that are commonly available for this process.

CONIFEROUS WOODS.

The results of the experiments on the various coniferous species are given in the following table:

Cook No.	Species of wood.	Total reducing sugars (per cent of original dry wood).	Per cent of total reducing sugars.		Alcohol yields.		
			Fermentable.	Unfermentable.	Per cent of original dry wood.	Gallons of absolute per dry ton.	Gallons of 190-proof per dry ton, allowing 5 per cent distillation loss.
63	White pine, Idaho	21.00	74.49	25.51	7.762	23.48	23.43
64	Red spruce	20.48	74.16	25.84	7.565	22.88	22.84
65	Douglas fir, Montana	21.10	[1] 67.42	[1] 32.58	6.822	20.64	20.59
66	White pine	20.02	75.67	24.33	7.437	22.48	22.46
67	Long leaf pine	23.06	73.32	26.68	8.282	25.05	24.90
68	do	23.25	72.49	27.51	8.330	25.20	25.16
69	Lodgepole pine	21.93	67.37	32.63	7.205	21.79	21.75
70	Norway pine extra large or small ships	25.62	66.88	33.12	7.745	23.42	23.38
71	Red spruce	22.06	72.67	27.33	7.956	24.06	24.01
50 [1]	Western larch	29.72	37.89	62.11	4.977	15.05	15.03
83 [2]	do	30.52	57.88	42.12	8.687	26.26	26.21
72 [3]	do	26.21	54.69	45.31	6.934	20.97	20.93
86	Western hemlock	21.15	77.63	22.37	7.622	23.05	23.01
99	Sugar pine	18.03	72.55	27.45	6.276	18.96	18.93
103	do	20.23	66.49	33.51	7.115	21.51	21.47
74	Douglas fir, Washington	21.13	75.16	24.84	7.934	23.99	23.95
46	White spruce	23.61	71.44	28.56	8.537	25.82	25 78

[1] 1.8 per cent of acid; 10 minutes cook.
[2] 2.5 per cent of acid; 20 minutes cook.
[3] 2.5 per cent of acid; 40 minutes cook.

The experiments on western larch will be considered separately. No great differences were found among the various other species. Those highest in cellulose, like white spruce and white pine, gave the best yields. The West Coast Douglas fir gave higher yields than the Montana mountain-grown fir. Cook No. 70 was on Norway pine chips left from the Yaryan extraction process, in which the turpentine had been steamed out and the rosin had been dissolved out with gasoline. The yield was probably 3 to 5 per cent higher than it would have been on the original wood basis, because of the difference in cellulose content calculated on a basis of freedom from volatile oil and rosin, as compared with the original wood. At the same time, the results of cooks Nos. 67 and 68 on true longleaf pine showed that the turpentine, pine oil, and rosin do not interfere in the production of the sugars from the wood or in the fermentation of the sugar liquors produced. However, sugar liquors produced from woods having appreciable quantities of volatile oils do contain some of the oils mentioned, and, unless particular care is exercised in the distillation and refining of the beers and alcohol made from such liquors, the alcohol finally obtained will contain some of those oils. On the other hand, it is not impossible to remove the oils, as evidenced by the fact that the finest Cologne spirits being produced in this country to-day is manufactured from longleaf pine.

Practically all the commercially available coniferous woods of this country are of equal value for alcohol production, and, as the waste from them constitutes the greater portion of the mill waste of the country, the results obtained from the experiments with them are naturally the most interesting. Cypress and the cedars were not tried; and the writer has no data to present regarding them except commercial results obtained from cypress in mixture with longleaf pine. As the exact composition of the mixture is not known, no positive data can be offered; it may, however, be said that cypress seems to give yields only from 60 to 75 per cent as good as pine.

The different results obtained in cooks Nos. 50, 83, and 72 on western larch are due to differences in material as well as in treatment. The differences will be considered in greater detail later. Cook No. 50 was made on material from the butt log, which is usually left in the woods, and with 1.8 per cent acid at 7.5 atmospheres for 10 minutes. Cooks Nos. 72 and 83 were made with 2.5 per cent of acid, the first for 20 minutes and the second for 40 minutes. Unfortunately, all three cooks were not made on material from the same sample, although cooks Nos. 72 and 83 were on the same sample and indicate a tendency toward an increase of fermentable sugars with an increase in the time of cooking. This tendency is probably due to pentose decomposition, as it was with spruce. The high figure for total sugars is due to the production of galactose, which is not fermentable under ordinary conditions, and the figures for fermentable sugars are therefore correspondingly lower than they are in the other coniferous woods.

BROAD-LEAVED WOODS.

The broad-leaved woods neither give the yields obtained from the coniferous woods, nor do they exhibit the uniformity of yield shown by the coniferous species. The yields of total sugars are sometimes nearly as great as those obtained from the coniferous species; but, as the following table shows, the portion of the total sugars fermentable is very much less than that from the coniferous species:

Cook No.	Species of wood.	Total reducing sugars, per cent of original dry wood.	Per cent of total reducing sugars.		Alcohol yields.		
			Fermentable.	Unfermentable.	Per cent of original dry wood.	Gallons of absolute per dry tons.	Gallons of 190-proof per dry ton allowing 5 per cent distillation loss.
62	Birch	20.53	46.29	53.71	4.288	12.97	12.95
73	Hard maple	18.93	34.04	65.96	3.029	9.16	9.14
75	Silver maple	20.74	47.22	52.78	4.661	14.10	14.07
76	Beech	21.24	22.22	77.78	1.995	6.03	6.02
77	White oak	17.30	50.48	49.52	4.102	12.40	12.38
78	Red oak	18.38	30.40	69.59	2.675	8.09	8.07
79	Sycamore	18.30	38.86	61.14	3.205	9.69	9.67
80	Slippery elm	16.60	26.79	73.21	1.382	5.99	5.98
81	Red gum	20.42	38.81	61.19	3.658	11.06	11.03
82	Cottonwood	18.19	32.86	67.14	2.392	7.23	7.21

The reason for these marked differences between the evergreens and the deciduous trees must reside in their chemical composition rather than in any physical or structural differences and, no doubt, may be ascribed primarily to differences in cellulose content. As a class, the deciduous trees contain less cellulose and more lignin and wood gums than the coniferous species. The gums, such as xylan and araban, are in part converted into the respective pentose sugars. This accounts for the comparatively high total sugar yields and also for the comparatively small portion of the sugar that is fermentable. Those constituents, lignin and gums, which make the hardwoods as a class, and especially beech, birch, and maple, desirable in destructive distillation, bring about a different result in alcohol production, and it is questionable whether commercial recovery would be possible from any of those species alone that are mentioned in the above table. If mixed in small amounts with coniferous waste, the broad-leaved species will not interfere with the production of sugar and alcohol from the coniferous waste, in spite of the large amounts of acetic and formic acids produced. In fact, it is when the recovery of these acids is considered in conjunction with the alcohol process that hardwood waste utilization appears possible if the waste is available in sufficient quantity.

Ordinary destructive distillation practice recovers 180 pounds of crude acetate of lime per cord of wood. Under good conditions this may be brought up to 200 or 220 pounds per cord.

The following table shows the amounts of acetic and formic acid produced from beech, birch, and maple, the three species commonly distilled:

Cook No.	Species.	Acetic acid (per cent of original dry wood).	Formic acid (per cent of original dry wood).	Total volatile acid (per cent of original dry wood).
76	Beech	4.800	0.445	5.245
62	Birch	4.700	.706	5.406
73	Hard maple	3.770	.512	4.282

The amounts of acetic acid produced, as shown in the above table, are equal to or greater than the amounts produced by the destructive-distillation process; and, aside from the technical value of the facts disclosed, additional light is thrown on the difference in chemical composition of those woods and woods of the coniferous species.

SOURCE OF FERMENTABLE SUGAR.

As previously outlined, the source of the fermentable sugar obtained from the hydrolysis of wood has long been a mooted question. Cellulose and materials higher in cellulose than wood, however, have

yielded fermentable sugars and alcohol in proportion to their cellulose content. In order to throw additional light on this subject, and also to ascertain whether another common waste material other than mill waste could be used for the production of alcohol, cook No. 50 was made on western larch.

The logging of western larch shows a woods loss of about 8 per cent, caused by butting off the lower portion of the tree.[46] The presence of shakes in the butt is chiefly responsible for this practice. In addition, the base of the tree is usually swollen. This portion is denser than the rest of the trunk, and usually sinks, thus preventing rafting. The length of the butts left in the woods varies from 4 to 8 feet, although a 16-foot piece is sometimes rejected.

Hitherto the utilization of this waste material has not met with success, and it was hoped that it might profitably be employed as a raw material in the production of alcohol. A sample of sawdust from a butt log was cooked with 1.8 per cent of sulphuric acid, 125 per cent of water, 7.5 atmospheres of pressure, for 10 minutes. A yield of sugars equal to 29.72 per cent and of total solids equivalent to 35.18 per cent of the dry weight of the wood was obtained. Under the same conditions white spruce would yield from 22 to 23 per cent of total sugars of which 60 to 65 per cent would be fermentable, making an alcohol yield of 6.8 to 7 per cent of the dry weight of the wood. The extracts obtained from the hydrolysis of the larch were fermented under standard conditions, the fermentation records and the alcohol yields being shown in the tables in the Appendix.

The larch yielded about 35 per cent more of total sugars than did the spruce, and yet only 37.9 per cent of that sugar fermented as compared with 60 or 65 per cent of the total sugar from spruce. A. W. Schorger, of the Forest Products Laboratory, has analyzed both of these woods with the following results:

	Western larch (base) (per cent).	White spruce (4 samples).	
		Range (per cent).	Mean (per cent).
Soluble in ether	9.75	0.90 to 1.95	1.36
Soluble in cold water	14.47	.82 to 1.45	1.12
Soluble in hot water	16.52	1.88 to 2.52	2.14
Soluble in 1 per cent of NaOH, 10 minutes heating	32.72	6.72 to 8.84	7.70
Soluble in 1 per cent of NaOH, 60 minutes heating	38.58	11.18 to 13.87	12.21
Pentosan	6.99	10.04 to 10.78	10.39
Methyl pentosan	3.42	3.08 to 3.95	3.55
Cellulose	42.57	51.95 to 58.47	56.17
Volatile oil	.84		
Ash	.36	.285 to .326	.307

It will be noticed that the larch contained a large amount of material soluble in water and a proportionately small amount of cel-

[46] U. S. Department of Agriculture, Forest Service, Bulletin 122, "The Mechanical Properties of Western Larch," by O. P. M. Goss.

lulose. The chief constituent of this material soluble in water was a galactan that yielded approximately 10 to 12 per cent of the dry weight of the wood of galactose, and this in turn accounts for the high sugar yields from the larch. If the sugar yield of the larch were recalculated, so that it would be proportionate to the cellulose content (22 per cent being assumed as the yield of sugar from spruce), there would then be 16.7 per cent of sugar instead of 29.7 per cent, as actually obtained. However, as noted above, about 10 or 12 per cent of galactose was obtained. If this were subtracted from the total sugar yield of 29.7 per cent, there would remain 18 or 19 per cent of sugar comparable to the yield obtained from spruce. Under normal conditions, with a good fermentation and on the assumption that 60 to 65 per cent of the total sugar would be fermentable, there would be an alcohol yield of 4.8 to 5.2 per cent; whereas the actual alcohol yield obtained from the larch is 4.997 per cent. This corresponds to about 62 per cent of the total sugars fermentable, which is the average of the above figures chosen for spruce. It appears, therefore, that the yield of fermentable sugars and of alcohol is proportionate to the cellulose content of the wood, as suggested by Körner,[47] but disputed by Gallagher and Pearl,[48] irrespective of other materials that may be present in the wood.

Western larch butts will be a good raw material for the production of ethyl alcohol if a yeast is found that will ferment the galactose as well as the dextrose within the time limit and under the other conditions as prescribed by the Bureau of Internal Revenue.

In addition to the evidence regarding the source of the fermentable sugars that was presented in the description of the results obtained from the broad-leaved woods, cook No. 98 was made on the leached residue from cook No. 95, which had been given a chlorine and sulphuric acid treatment. Cooking this residue with 2.5 per cent of sulphuric acid gave only 6.56 per cent of total sugars as compared with the 22 per cent normally obtained from spruce. Through an accident the sugar liquor was lost and no fermentations were made, but the data obtained shows the small yield of sugars obtainable on reinversion, and also indicates that the source of the sugars is the cellulose; for, if the lignin as well as the cellulose were the source, as much sugar would be obtained from the residue as from the original wood, equal weights of material being compared.

BY-PRODUCTS.

From longleaf pine and the other pines of the South, about 1 gallon of crude turpentine per cord, consisting of the higher-boiling fractions of turpentine and pine oil, can be recovered from the blow-

[47] Zeit. für ang. Chemie., 1908, 2353.
[48] Proc. Eighth International Congress of Appl. Chemistry, vol. 13, p. 147.

off. The commercial values of the beer-still slops that contain the unfermented pentoses, and of the solid residue from the diffusion battery are being investigated. Recent investigations point to the use of the latter as a stock food. The potential value of both of these by-products is very great, and their investigation is exceedingly interesting both as a chemical and as a commercial question.

ANALYSIS OF RESULTS.

In a review and summary of the results obtained from the experiments described in this paper, the following points seem to be established for coniferous woods:

1. The temperature and pressure of cooking should not exceed 7.5 atmospheres (112 to 115 pounds per square inch).

2. This temperature and pressure should be reached as soon as technically possible, and the boiler capacity of the plant should be such that this may be accomplished in 15 or 20 minutes.

3. The digester contents should be cooked at the above pressure and temperature for 15 or 20 minutes. This requires only enough steam for radiation.

4. The ratio of water to dry wood should be about 125 parts of water to 100 parts of dry wood.

5. The ratio of sulphuric acid (100 per cent) to dry wood should be from 1.8 to 2.5 parts of acid to 100 parts of dry wood.

6. Under the above conditions a yield of 25 gallons of 190-proof alcohol per dry ton has been obtained, allowance being made for a distillation loss of 2.5 per cent, but no allowance being made for any manufacturing losses.

7. After the cooking, the digester should be blown off as quickly as possible. If the plant is operating on longleaf pine or a similar resinous wood, about 1 gallon of crude turpentine can be recovered per cord. If the plant is operating on other coniferous species, the amount of turpentine in the blow-off will not pay for recovery; and the same thing is true of the volatile acid in all coniferous species. Usually the digester may be blown off directly into the air.

8. Under the above conditions a complete cycle for each digester would be about as follows:

	Minutes.
Loading	5 to 5
Heating	15 to 20
Cooking	15 to 20
Blowing-off	5 to 8
Discharging	5 to 7
Total	45 to 60

9. Broad-leaved woods produce only about one-half as much fermentable sugars and alcohol as do coniferous woods, although the

volatile-acid production from some of the broad-leaved woods is as great as that from the same species by the destructive-distillation process.

10. Sulphuric acid and possibly some sulphates are the best catalysts if cost, technical conditions, and yields are all considered.

11. Chlorides prohibit fermentation, but tannin in the concentrations as ordinarily obtained does not.

PLANT EQUIPMENT AND OPERATION.

The essential parts of a plant equipped to produce ethyl alcohol from wood, considered in the order of their use, are as follows:

1. Adequate sawdust storage.
2. Disintegrating equipment—hogs, screens, and shredders.
3. Sawdust storage above digesters, and acid storage.
4. Digesters.
5. Diffusion battery.
6. Neutralizing and settling tanks.
7. Coolers.
8. Fermenters and yeast equipment.[49]
9. Beer still.[49]
10. Rectifying still.[49]
11. Bonded warehouse.[49]
12. Boilers and engines.
13. Laboratory and office.
14. Charcoal rectifiers (desirable, but not absolutely necessary).

SAWDUST STORAGE.

What constitutes adequate sawdust storage will depend upon the location and the continuity of operation of the sawmill and upon the character of the logging operation. The operation of the alcohol plant and distillery must be continuous. The storage, therefore, must be adequate to make it possible for the plant to comply with the regulations of the Bureau of Internal Revenue governing the operation of distilleries. These alcohol plants are surveyed as to their output and must produce daily the amount required in the survey; if they do not produce that amount, they are penalized with the tax on such a quantity of alcohol as is necessary to make up the amount required by the survey. In general, therefore, the alcohol plant should have at least 15 days' supply of wood on hand; and, if the logging operations require frequent shutdowns, the alcohol plant should always have sufficient material in storage to last twice as long as the average shutdown. The waste may be best stored and handled in the condition in which it is ready for use, that is, hogged and shredded. Protection from the rain is all that is needed, and any type of open-walled, covered building would be suitable. Belt conveyors may be used to handle the material, and

[49] These items must be approved and supervised by the U. S. Bureau of Internal Revenue.

a long, open, covered shed with an inclined bottom sloping into a trough, similar to those used for the storage of sugar beets, would answer the purpose; or the material may be windrowed in piles and permitted to hopper itself, the danger of its rotting in the hoppers being obviated by this plan.

All hoppers, both in the storage building and over the digesters, as well as all other parts of these buildings coming in contact with the hogged and shredded waste, should be either of steel or of heavily creosoted timber construction in order that decay may be avoided. The green shredded wood makes an ideal medium for the cultivation of wood-destroying fungi, and even in exposed places too dry, it would seem, for decay to take place, the writer has found it progressing rapidly wherever there were accumulations of fine stuff.

DISINTEGRATING EQUIPMENT.

The disintegrating equipment should consist of hogs or chippers, shredders, and screens. A chip one-half an inch long in the direction of the grain will be penetrated thoroughly with acid, but the ease with which the sugar can be leached out is a problem that requires attention. However, as the residual digested sawdust or waste after extraction is ample for power production, and as all exhaust steam from the engine has value for heating and distillation purposes, the extra power required to chip down to a three-sixteenths or one-quarter inch chip would not be prohibitive, and the greater efficiency of extraction would probably make the chipping down very desirable. After being screened—for the screenings should be reshredded—the fine stuff should go by belt to the loading bin over the digester.

SAWDUST AND ACID STORAGE.

The loading bins should be of sufficient size to serve as intermediate storage for the material as it comes from the screen on its way to the digester. Each of the bins should hold several digesterfuls and should be placed over the digester, being tapered down so that the material may flow directly into the digester, according to the arrangement in chemical-pulp plants.

The acid intended for the plant should be in concentrated form, to permit of shipment in tank cars and storage in steel tanks. The concentrated acid should be pumped into a lead-lined tank above the digester and be diluted in order that the dilute acid may flow into the digester along with the sawdust. If rotating digesters are used, no special mixing apparatus will be necessary; at least, no appreciable quantities of uncooked material have ever been found at the Forest Products Laboratory when such digesters were used.

DIGESTERS.

The digesters should be of the rotating kind, and may be spherical or in the form of a short cylindrical section with dished ends. If they are of the latter type, the diameter should be double the length of the cylindrical section in order that the digester may be filled as nearly full as possible. A number of satisfactory acid-proof linings are now obtainable. During the cooking the mass shrinks in volume and settles, the final volume being only about two-thirds the original volume. There is, therefore, ample room for thorough mixing during the cooking.

The size of the digesters will be governed by the daily capacity of the plant, the heating period, and the time of the complete cycle for each digester. If the heating period is 15 minutes out of a total of 1 hour for each cook, four digesters or multiples of four should be used; whereas if the heating period is 20 minutes out of a total of 1 hour, only three or multiples of three should be used. In this way the steam load on the boilers will be made as uniform as possible. The boiler capacity will be largely determined by this load, since that for power and distillation purposes will usually be constant. In addition, the hogging, shredding, and digester capacity of the plant should be sufficient to give enough digested sawdust in 18 or 20 hours to run the rest of the plant 24 hours, thereby allowing time for breakdowns and repairs.

By the rotation of the digester the cooked sawdust is discharged and falls into a large bin, which receives this material from all the digesters. From this bin it goes by mechanical conveyor to the different cells of the diffusion battery.

DIFFUSION BATTERY.

Closed cells similar to those used for the extraction of sugar beets or dyewood chips may be used. These should be lined and made acid-resistant like the digesters, and are usually fitted with bronze and copper. The top and bottom should be so arranged that charging and discharging may be readily accomplished. Cells of this type may be obtained from which the extracted material will empty itself when the bottom of the cell is released.

The temperature of the extracting water will rise 30° to 50° F. during extraction because of the hot dust. In cold weather it would be advisable to warm the water before it is used. If the acid juice comes from the battery with a temperature between 125° and 150° F., a good extraction will be obtained, and the large volumes of water that would be required to cool hotter juice will not be necessary.

The size and number of cells in the battery and the amount of water in each cell will be governed by the size of the plant and the

size of the material that is to be cooked, as, for instance, sawdust will extract more readily than larger material. As the sugars are readily soluble, only a short extraction period is necessary—that is, from 5 to 10 minutes on each cell—making a total extraction period of 50 to 75 minutes. This period, however, will be governed in part by the length of time that it takes the water to drain through each cell, and this in turn depends on the size of the cell.

The cells should not be too large, else the extracting water will not pass through the material easily, and there will be a tendency to channel. The amount of water used should be such as to make the resulting acid extract 11° to 12° Brix, the proper concentration for fermentation. The Brix will rise another degree on neutralization.

As in laboratory work, so in regular practice, a large number of extractions or washings with small amounts of liquid will give a better extraction or a more thorough washing with a more concentrated extract than will fewer extractions with larger amounts of water for each extraction.

NEUTRALIZATION AND SETTLING.

After extraction the acid extract is nearly neutralized with lime or a high-grade limestone. For this purpose a magnesia stone is undesirable. For a number of reasons it has been found preferable to cool the acid juice to 100° F. or less before it is neutralized. During neutralization the temperature will rise a few degrees. The extract is then allowed to stand and settle out the sludge of calcium sulphate. As this usually requires from 15 to 18 hours, adequate tank capacity is required.

COOLERS.

The clear juice is then drawn off and passed through coolers to reduce its temperature to from 80° to 90° F., after which it goes into the fermenting tanks. The coolers should be of copper, and their size will depend upon the temperature of the water supply available. As the calcium sulphate in the neutral juice will partially crystallize out during the cooling, the coolers should be so designed as to be easily taken apart and cleaned.

FERMENTATION, DISTILLATION, ETC.

A 96-hour fermentation period is permitted; hence a 4-day fermenter capacity is required. The size of the individual fermenter will be determined largely by the outdoor mean temperature and other local conditions. The other apparatus is the standard distillery equipment in use in grain and molasses distilleries.

POWER REQUIREMENTS.

The steam load of the plant will be distributed about as follows:

	Per cent.
Pumps—boiler, fire, general water supply, beer, alcohol	20
Digesters	30
Hogs and shredders	20
General power for driving conveyors, digesters, etc	15
Distillation and rectification, (including all exhaust steam not used for heating boiler-feed and extraction water)	15
	100

A large supply of pure, cool water is also necessary. It should be pure for boiler and extraction purposes, and cool for use in cooling and condensing. The disposal of the beer-still slop requires attention, because it contains a large amount of pentose carbohydrate and dead yeast; the latter of which is highly nitrogenous. However, the slop does not putrefy on standing and will maintain a nearly sterile condition for a long time.

COSTS.

As outlined before, the commercial production of alcohol by this process, with two exceptions, has not been a success. If such a yield is assumed, however, as that obtained at the Forest Products Laboratory, and if the necessary manufacturing losses are allowed, as for instance, the extraction loss in the sludge of the settled juice, and the distillation and rectification losses (which, combined, should not be over 20 per cent of the total product), a yield of about 20 gallons a dry ton is obtained. Assuming this yield, and a location in which the supply of waste will be uniform and constant for a period of 20 years, and in which plenty of good water may be had, with a supply of sulphuric acid and lime reasonably nearby, the cost of a gallon of 190-proof alcohol from wood in a properly designed and constructed plant having a capacity of 2,500 or 3,000 gallons a day, is estimated to be as follows:

Yeast nutrients	$0.015 to	$0.020
Repairs and materials (exclusive of fuel and wood)	.030 to	.040
Labor	.015 to	.030
Wood and fuel	.020 to	.020
Interest at 7 per cent	.019 to	.020
Depreciation at 10 per cent	.023 to	.035
Overhead, taxes, etc	.015 to	.030
Total	.137 to	.195

In the above table wood has been valued at 40 cents a cord, 1,800 pounds of dry wood being considered to be a cord. This wood should consist of sawdust and hogged refuse, but should not contain over 10 per cent of bark, as the yield of sugars and alcohol from bark is

very low. A large quantity of bark would mean running a large volume of inert material through the alcohol plant at considerable expense and without return. Moreover, the use of most barks would add large quantities of tannin to the solutions to be fermented, and this also is undesirable.

If all waste is disposed of for this purpose, a sawmill could not only net the price of 40 cents a cord mentioned above, but it could also avoid the cost of burning the waste, which, as given before, ranges from 30 to 66 cents a cord. To the sawmill this would mean a net gain practically double the figure at which the waste is sold.

The successful production of ethyl alcohol from sawdust seems to depend upon the proper design, equipment, and management of the plant, rather than upon the improvement of the chemical or fermentological features of the process. The problem involves the quick and efficient handling of large volumes of low-grade material under unusual technical conditions, the perfecting of the necessary acid-resisting pieces of apparatus, a study of the experience of the plants that have been built and operated, and the efficient utilization of material whose mere removal is now an expense. This industry unquestionably is worthy the serious study of experimental and practical investigators of the utilization of forest products.

TABLE 1.—*Sugar and alcohol yields.*

Species of wood.	Fermentation No.	Cook No.	Total reducing sugars (per cent of original dry wood).	Per cent of total reducing sugars.		Fermentation efficiency.	Alcohol in beer.		Per cent of total sugars obtained as alcohol.	Alcohol yields.			Remarks.
				Fermentable.	Nonfermentable.		Actual alcohol yield.	Theoretical alcohol yield.		Per cent of original dry wood.	Gallons of absolute per dry ton.	Gallons of 190-proof per dry ton, allowing 5 per cent distillation loss.	
White spruce	.....	21	23.16	54.57	45.43	83.20	1.818	2.185	45.40	5.374	16.255	16.224	
	.....	21	23.16	55.17	44.83	104.38	1.452	1.391	57.59	6.817	20.619	20.581	
				54.87	45.13					6.096	18.44	18.40	Average.
	.....	22	23.75	55.01	44.99	96.68	2.443	2.527	53.18	6.455	19.524	19.488	
	.....	22	23.75	55.61	44.39	101.34	2.271	2.241	56.36	6.841	20.692	20.653	
	.....	22	23.75	54.44	35.56	107.70	.783	.727	69.40	8.424	25.480	25.432	Discard.
				55.31	44.69					6.648	20.11	20.07	Average.
	.....	23	23.55	54.22	45.78	101.19	2.128	2.103	54.87	6.607	19.984	19.946	
	.....	23	23.55	55.09	44.91	94.37	2.045	2.167	51.99	6.260	18.935	18.899	
				54.66	45.34					6.434	19.46	19.42	Do.
	.....	24	23.81	53.76	46.24	95.21	1.849	1.942	51.18	6.228	18.838	18.802	
	.....	24	23.81	52.45	47.55	93.73	1.778	1.897	49.16	5.982	18.094	18.060	
	.....	24	23.81	53.26	46.74	106.08	2.364	2.228	56.50	6.876	20.798	20.759	
				53.16	46.84					6.362	19.24	19.21	Do.
	.....	25	25.01	54.93	45.07	97.69	2.115	2.165	53.66	6.859	20.746	20.707	
	.....	25	25.01	58.20	41.80	96.97	2.340	2.413	56.44	7.210	21.808	21.767	
	.....	25	25.01	54.75	45.25	98.37	2.180	2.216	53.86	6.885	20.825	20.786	
				54.84	45.16					6.985	21.13	21.09	Do.
	.....	26	22.24	58.18	41.82	92.56	2.141	2.313	53.85	6.121	18.514	18.479	
	.....	26	22.24	53.79	46.21	97.93	2.314	2.363	52.67	5.987	18.109	18.075	
	.....	26	22.24	56.61	43.39	98.77	2.334	2.363	55.91	6.355	19.222	19.186	
				56.19	43.81					6.154	18.61	18.58	Do.

TABLE 1.—*Sugar and alcohol yields*—Continued.

Species of wood.	Fermentation No.	Cook No.	Total reducing sugars (per cent of original dry wood).	Per cent of total reducing sugars.		Fermentation efficiency.	Alcohol in beer.		Per cent of total sugars obtained as alcohol.	Alcohol yields.			Remarks.
				Fermentable.	Nonfermentable.		Actual alcohol yield.	Theoretical alcohol yield.		Per cent of original dry wood.	Gallons of absolute per dry ton.	Gallons of 190-proof per dry ton, allowing 5 per cent distillation loss.	
Shortleaf pine	.....	27	18.57	56.21	43.79	91.74	1.811	1.974	51.57	4.893	14.800	14.772	
	.....	27	18.57	54.25	45.75	103.85	2.40	2.311	56.34	5.858	17.719	17.685	
				55.23	44.77					5.376	16.255	16.228	Average.
	.....	28	5.34	32.29	67.71	101.11	.453	.448	32.65	.891	2.710	2.690	
	.....	29	16.37	56.52	43.48	84.69	1.494	1.764	47.87	4.00	12.099	12.076	
	.....	29	16.37	53.15	46.85	106.30	1.265	1.190	56.50	4.727	14.298	14.271	
	.....	29	16.37	53.85	46.15	87.84	2.008	2.286	47.30	3.957	11.959	11.946	
				54.51	45.49					4.226	12.78	12.76	Do.
White spruce	.....	30	21.09	60.09	39.91	91.89	1.619	1.762	55.22	5.952	18.093	17.969	
	.....	30	21.09	61.26	38.74	104.98	2.322	2.213	64.27	6.928	20.955	20.916	
				60.68	39.32					6.440	19.48	19.44	Do.
	.....	31	21.45	63.56	36.44	101.58	2.189	2.156	64.56	7.078	21.409	21.368	
	.....	31	21.45	63.76	36.24	95.00	2.299	2.420	60.57	6.640	20.684	20.646	
	.....	31	21.45	42.14	57.86	99.74	1.586	1.590	42.03	4.096	12.389	12.366	Discard.
				63.66	36.34					6.859	20.75	20.71	Average.
	.....	32	21.32	69.45	30.55	99.18	2.169	2.187	68.88	7.506	22.703	22.661	
	.....	32	21.32	58.97	41.03	146.77	2.956	2.014	86.55	9.431	28.526	28.472	Discard.
	.....	32	21.32	38.47	61.53	95.68	1.153	1.205	36.81	4.011	12.132	12.109	Do.
	.....	32	21.32	70.12	29.88	93.85	2.016	2.148	65.82	7.171	21.690	21.649	
				69.79	30.21					7.339	22.20	22.16	Average.
	.....	33	23.17	54.46	45.54	113.64	3.066	2.698	61.89	7.320	22.168	22.126	
	.....	33	23.17	53.93	46.07	103.57	2.409	2.326	55.86	5.615	20.008	19.971	
				54.20	45.80					6.972	21.09	21.05	Do.

.....	34	21.96	.....	.....	.....	.....	.....	.....	.....	.....	.....	
.....	34	21.96	59.08	40.92	100.63	2 887	2.869	59.53	6.682	20.211	20.173	
.....	34	21.96	59.49	40.51	103.75	2.463	2.374	61.72	6.927	20 952	20.913	
.....	34	21.96	53.56	46.44	95.94	2.243	2.338	51.39	5.768	17.446	17.414	Discard.
			59.29	40.71					6.805	20.58	20.54	Average.
.....	35	21.68	56.06	43.94	107.27	3.348	3.121	60.14	6.664	20.157	20.119	
.....	35	21.68	56.80	43.20	100.85	2.737	2.714	57.28	6.347	19.198	19.162	
			56.43	43.57					6.506	19.68	19.64	Do.
.....	36	21.10	65.71	34.29	95.62	2.316	2.422	62.83	6.776	20.495	20.457	
.....	36	21.10	69.03	30.97	96.97	2.114	2.180	66.94	7.219	21.835	21.794	
.....	36	21.10	65.15	34.85	99.72	1.824	1.829	64.97	7.006	21.191	21.151	
			66.63	33.37					7.000	21.17	21.13	Do.
.....	37	21.83	55.25	44.75	99.52	3.079	3.094	54.98	6.135	18.557	18.522	
.....	37	21.83	55.52	44.48	98.97	2.403	2.428	54.95	6.131	18.544	18.509	
.....	37	21.83	57.31	42.69	93.70	2.336	2.493	53.70	5.990	18.118	18.984	
			56.03	43.97					6.085	18.41	18.37	Do.
.....	38	17.42	42.40	57.60	115.31	1.732	1.502	48.89	4.363	13.167	13.142	
.....	38	17.42	44.63	55.37	111.53	1.673	1.500	49.78	4.432	13.405	13.380	
.....	38	17.42	42.36	57.64	103.44	1.382	1.336	43.82	3.901	11.799	11.777	
			43.13	56.87					4.172	12.62	12.60	Do.
.....	39	22.37	52.53	47.47	100.55	2.564	2.550	52.82	6.039	16.266	18.232	
.....	39	22.37	53.18	46.82	105.79	2.121	2.005	56.26	6.432	19.455	19.418	
.....	39	22.37	56.05	43.95	96.31	1.983	2.059	53.98	6.172	18.668	18.633	
			53.92	46.08					6.214	18.80	18.76	Do.
.....	40	23.74	63.83	36.17	91.92	2.424	2.637	58.67	7.119	21.533	21.492	Discard.
.....	40	23.74	33.93	66.07	109.00	1.501	1.377	36.98	4.487	13.572	13.546	
.....	40	23.74	53.67	46.33	97.03	2.483	2.559	52.08	6.319	19.113	19.077	
			53.67	46.33					6.319	19.11	19.08	Average.
.....	41	23.09	57.18	42.82	99.14	2.415	2.436	56.69	6.690	20.235	20.197	
.....	41	23.09	56.80	43.20	95.46	2.397	2.511	54.22	6.399	19.355	19.319	
.....	41	23.09	32.95	67.05	102.66	1.390	1.354	33.83	3.992	12.075	12.052	Discard.
.....	41	23.09	47.20	52.80	101.06	2.008	1.987	47.70	5.629	17.026	16.994	Do.
.....	41	23.09	45.46	54.54	101.90	2.199	2.158	46.32	5.466	16.533	16.502	Do.
			56.99	43.01					6.550	19.81	19.77	Average.

TABLE 1.—*Sugar and alcohol yields*—Continued.

Species of wood.	Fermentation No.	Cook No.	Total reducing sugars (per cent of original dry wood).	Per cent of total reducing sugars.		Fermentation efficiency.	Alcohol in beer.		Per cent of total sugars obtained as alcohol.	Alcohol yields.			Remarks.
				Fermentable.	Nonfermentable.		Actual alcohol yield.	Theoretical alcohol yield.		Per cent of original dry wood.	Gallons of absolute per dry ton.	Gallons of 190-proof per dry ton, allowing 5 per cent distillation loss.	
White spruce	.....	42	22.34	40.22	59.78	99.42	1.533	1.542	39.99	4.566	13.811	13.785	Discard.
	.....	42	22.34	53.44	46.56	116.40	2.356	2.024	62.20	7.102	21.480	21.441	Do.
	.....	42	22.34	60.99	39.01	94.38	2.501	2.650	57.56	6.572	19.878	19.841	
	.....	42	22.34	26.88	73.12	118.30	1.138	.962	31.80	3.631	10.983	10.962	Do.
	.....	42	22.34	64.14	35.86	91.50	2.745	3.000	58.69	6.701	20.269	20.230	
	.....	42	22.34	64.58	35.42	96.77	2.488	2.571	62.49	7.135	21.581	21.541	
	.....	42	22.34	63.16	36.84	97.64	2.439	2.498	61.67	7.041	21.297	21.257	
				63.22	36.78					6.862	20.760	20.72	Average.
	.....	43	21.84	55.17	44.83	107.27	2.258	2.105	59.18	6.606	19.981	19.944	
	.....	43	21.84	58.95	41.05	100.00	2.278	2.278	58.95	6.580	19.903	19.865	
	.....	43	21.84	58.34	41.66	97.32	2.720	2.795	56.78	6.338	19.171	19.134	
	.....	43	21.84	57.70	42.30	99.86	2.815	2.819	57.62	6.432	19.455	19.418	
	.....	43	21.84	59.10	40.90	93.34	2.297	2.461	55.16	6.157	18.623	18.588	
	.....	43	21.84	58.38	41.62	93.59	2.116	2.261	54.64	6.099	18.448	18.413	
				57.94	42.06					6.369	19.26	19.23	Do.
	.....	44	23.00	56.94	43.06	93.67	2.589	2.764	53.34	6.270	18.965	18.929	
	.....	44	23.00	54.22	45.78	103.19	2.752	2.667	55.95	6.577	19.893	19.856	
	.....	44	23.00	58.91	41.09	100.31	2.258	2.251	59.09	6.946	21.010	20.970	
	.....	44	23.00	58.56	41.44	99.73	2.536	2.543	58.40	6.865	20.765	20.725	
				57.16	42.84					6.665	20.16	20.12	Do.
	.....	45	22.77	62.78	37.22	92.28	2.319	2.513	57.93	6.742	20.393	20.354	
	.....	45	22.77	62.10	37.90	97.62	2.990	3.063	60.62	7.055	21.339	21.299	
	.....	45	22.77	64.06	35.94	91.84	2.632	2.866	58.83	6.846	20.707	20.668	
	.....	45	22.77	41.32	58.68	96.74	1.217	1.258	39.97	4.652	14.071	14.044	Discard.
	.....	45	22.77	61.65	38.35	102.20	2.595	2.539	63.01	7.333	22.180	22.138	
				62.65	37.35					6.994	21.15	21.11	Average.

	.....	46	23.61	70.93	29.07	101.84	2.548	2.502	72.24	8.717	26.366	26.317	
	.....	46	23.61	72.56	27.44	95.30	2.130	2.235	69.15	8.344	25.238	25.191	
	.....	46	23.61	34.24	65.76	117.73	1.089	.925	40.31	4.864	14.712	14.684	Discard.
	.....	46	23.61	70.83	29.17	100.04	2.226	2.225	70.86	8.551	25.864	25.815	
				71.44	28.56					8.537	25.82	25.77	Average.
	.....	47	23.40	67.70	32.30	97.92	2.830	2.890	66.29	7.928	23.980	23.935	
	.....	47	23.40	68.47	31.53	99.89	2.713	2.716	68.39	8.179	24.739	24.692	
	.....	47	23.40	68.01	31.99	101.59	2.485	2.446	69.09	8.263	24.993	24.946	
	.....	47	23.40	64.88	35.12	97.52	2.321	2.360	63.27	7.567	22.888	22.845	
				67 27	32.73					7.984	24.15	24.10	Do.
Shortleaf pine	.....	48	17.15	61.09	38.91	98.78	2.588	2.620	60.34	5.289	15.998	15.967	
	.....	48	17.15	58.26	41.74	92.08	2.070	2.248	53.65	4.702	14.222	14.195	
	.....	48	17.15	61.35	38.65	104.39	2.186	2.094	64.04	5.613	16.978	16.946	
				60.27	39.73					5.201	15.73	15.70	Do.
	.....	49	14.02	65.08	34.92	92.57	1.707	1.844	60.24	4.316	13.055	13.030	
	.....	49	14.02	68.09	31.91	86.22	1.514	1.756	58.71	4.207	12.725	12.701	
				66.59	33.41					4.262	12.89	12.87	Do.
Western larch	.....	50	29.72	37.70	62.30	85.77	1.320	1.539	32.34	4.970	15.033	15.004	
	.....	50	29.72	39.83	60.17	79.85	1.470	1.841	31.80	5.048	15.269	15.240	
	.....	50	29.72	36.04	63.96	92.23	1.578	1.711	33.24	4.912	14.857	14.829	
				37.89	62.11					4.977	15.05	15.03	Do.
White spruce	.....	55	18.06	82.35	17.65	98.95	2.311	2.330	81.48	7.520	22.746	22.703	
	.....	55	18.06	81.41	18.59	100.88	2.259	2.239	82.11	7.580	22.927	22.884	
	.....	55	18.06	81.82	18.18	99.11	2.259	2.289	81.09	7.485	22.640	22.597	
	.....	55	18.06	81.37	18.63	98.34	2.345	2.381	79.02	7.294	22.062	22.021	
	.....	55	18.06	80.04	19.96	95.53	2.224	2.328	76.46	7.058	21.348	21.308	
				81.40	18.60					7.387	22.34	22.30	Do.
	.....	56	21.56	77.16	22.84	97.73	2.390	2.446	75.41	8.307	25.126	25.079	
	.....	56	21.56	77.68	22.32	98.09	2.395	2.440	76.20	8.395	25.392	25.345	
	.....	56	21.56	76.63	23.37	98.75	2.382	2.412	75.67	8.338	25.220	25.172	
	.....	56	21.56	77.53	22.47	97.80	2.315	2.367	75.82	8.355	25.271	25.224	
	.....	56	21.56	77.56	22.44	101.11	2.543	2.515	78.42	8.641	26.136	26.087	
	.....	56	21.56	76.85	23.15	91.83	1.968	2.143	70.57	7.776	23.520	23.475	
	.....	56	21.56	76.66	23.34	97.73	2.590	2.650	74.92	8.256	24.972	24.925	
				77.15	22.85					8.295	25.09	25.04	Do.

TABLE 1.—*Sugar and alcohol yields*—Continued.

Species of wood.	Fermentation No.	Cook No.	Total reducing sugars (per cent of original dry wood).	Per cent of total reducing sugars.		Fermentation efficiency.	Alcohol in beer.		Per cent of total sugars obtained as alcohol.	Alcohol yields.			Remarks.
				Fermentable.	Nonfermentable.		Actual alcohol yield.	Theoretical alcohol yield.		Per cent of original dry wood.	Gallons of absolute per dry ton.	Gallons of 190-proof per dry ton, allowing 5 per cent distillation loss.	
White spruce	.....	57	21.08	80.26	19.74	93.46	2.558	2.541	75.01	8.082	24.446	24.400	
	.....	57	21.08	78.73	21.27	100.07	2.543	2.468	78.78	8.488	25.674	25.625	
	.....	57	21.08	79.00	21.00	96.86	2.318	2.393	76.52	8.249	24.951	24.904	
	.....	57	21.08	78.09	21.91	95.16	1.909	2.006	74.31	8.006	24.216	24.170	
	.....	57	21.08	78.43	21.57	97.09	2.266	2.334	76.15	8.294	24.815	24.768	
	.....	57	21.08	78.91	21.09	97.64	2.274	2.329	77.05	8.301	25.108	25.060	
				78.90	21.10					8.222	24.87	24.82	Average.
	.....	58	22.82	60.62	39.38	98.84	2.218	2.244	59.92	6.989	21.140	21.100	
	.....	58	22.82	60.98	39.02	87.52	2.117	2.419	53.37	6.225	18.829	18.793	
	.....	58	22.82	60.29	39.71	99.43	2.421	2.435	59.95	6.992	21.149	21.109	
		58	22.82	59.95	40.05	98.52	2.500	2.535	59.12	6.895	20.855	20.816	
	.....	58	22.82	60.56	39.44	95.38	2.456	2.575	57.76	6.737	20.377	20.339	
				60.48	39.52					6.768	20.47	20.43	Do.
	.....	59	20.21	73.44	26.56	89.00	1.843	2.071	65.36	6.751	20.420	20.381	
	.....	59	20.21	74.19	25.81	93.10	2.147	2.306	69.07	7.134	21.578	21.538	
	.....	59	20.21	73.96	26.04	97.94	2.382	2.432	72.44	7.483	22.634	22.591	
	.....	59	20.21	72.41	27.59	95.40	2.694	2.824	69.08	7.136	21.584	21.544	
				73.50	26.50					7.126	21.55	21.51	Do.
	.....	60	21.005	70.44	29.56	95.94	2.246	2.341	67.58	7.255	21.944	21.903	
	.....	60	21.005	70.68	29.32	92.50	2.072	2.240	65.38	7.019	21.230	21.190	
	.....	60	21.005	[1] 58.37	[1] 41.63	112.68	2.469	2.191	65.77	7.061	21.357	21.317	
	.....	60	21.005	67.39	32.61	104.52	2.474	2.367	70.44	7.562	22.872	22.830	
	.....	60	21.005	67.76	32.24	98.63	2.517	2.552	66.83	7.175	21.703	21.661	
				69.07	30.93					7.214	21.82	21.78	Do.

	.....	61	20.14	70.77	29.23	97.94	2.381	2.431	69.31	7.134	21.578	21.538	
	.....	61	20.14	76.12	23.88	69.28	2.226	3.213	52.74	5.429	16.421	16.390	Discard.
	.....	61	20.14	71.55	28.45	96.18	2.495	2.594	68.82	7.084	21.427	21.387	
	.....	61	20.14	76.68	23.32	73.64	2.596	3.525	56.47	5.813	17.583	17.549	Do.
				71.16	28.84					7.109	21.50	21.46	Average.
Birch	22	62	20.53	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	23	62	20.53	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	24	62	20.53	49.15	50.85	88.83	1.095	1.306	21.06	4.323	13.08	13.05	
	25	62	20.53	43.43	56.57	92.91	.991	1.067	20.62	4.253	12.86	12.84	
				46.29	53.71					4.288	12.97	12.95	Do.
White pine, Idaho	22	63	21.00	73.74	26.26	98.54	2.184	2.216	37.14	7.799	23.59	23.54	
	23	63	21.00	73.84	26.16	97.14	2.450	2.522	36.96	7.761	23.47	23.43	
	24	63	21.00	73.76	26.24	95.72	2.172	2.269	36.08	7.577	22.92	22.88	
	25	63	21.00	73.98	26.02	102.24	2.244	2.195	38.66	8.118	24.55	24.51	
	26	63	21.00	77.14	22.86	91.26	2.105	2.306	35.98	7.557	22.86	22.81	
	29	63	21.00	74.49	25.51	88.18	.694	.866	17.87	7.762	23.48	23.43	
				74.49	25.51					7.762	23.48	23.43	Do.
Red spruce	22	64	20.48	73.24	26.76	98.90	2.852	2.884	37.02	7.582	22.93	22.89	
	23	64	20.48	75.24	24.76	96.46	2.908	3.015	37.09	7.597	22.98	22.93	
	24	64	20.48	75.05	24.95	93.24	2.284	2.450	35.77	7.325	22.16	22.11	
	25	64	20.48	73.13	26.87	101.27	3.222	3.182	37.85	7.755	23.46	23.41	
				74.16	25.84					7.565	22.88	22.84	Do.
Douglas fir, Montana	29	65	21.60	68.28	31.72	97.63	2.197	2.250	34.07	7.189	21.74	21.70	
	22	65	21.60	65.74	34.26	95.57	2.585	2.705	32.11	6.776	20.49	20.46	
	23	65	21.60	65.89	34.11	94.33	2.358	2.500	31.77	6.703	20.28	20.24	
	24	65	21.60	65.89	34.11	90.58	2.382	2.630	30.50	6.436	19.47	19.43	
	25	65	21.60	64.99	35.01	98.96	2.815	2.845	32.87	6.936	20.98	20.94	
	26	65	21.60	66.73	33.27	97.16	2.709	2.788	33.14	6.991	21.15	21.11	
	27	65	21.60	67.42	32.58	92.42	2.361	2.555	31.85	6.720	20.33	20.29	
				67.42	32.58					6.822	20.64	20.59	Do.
White pine	22	66	20.02	71.83	28.17	103.77	2.769	2.668	38.10	7.627	23.07	23.03	
	23	66	20.02	77.48	22.52	94.16	2.482	2.636	37.29	7.465	22.58	22.54	
	24	66	20.02	77.68	22.32	90.82	2.563	2.822	26.06	7.219	21.84	21.79	
				75.67	24.34					7.437	22.48	22.46	Do.
Longleaf pine	22	67	23.06	69.47	30.53	99.79	2.836	2.842	35.43	8.171	24.71	24.67	
	23	67	23.06	73.98	26.02	94.81	2.599	2.741	35.85	8.267	25.00	24.96	
	24	67	23.06	75.20	24.80	89.68	2.560	2.855	34.47	7.949	24.04	24.00	
	25	67	23.06	73.08	26.92	97.83	2.589	2.646	36.54	8.426	25.49	25.44	
	26	67	23.06	72.94	27.07	74.12	2.640	3.562	29.88	8.204	24.81	24.77	

[1] Large chips of white spruce were used in this cook.

TABLE 1.—*Sugar and alcohol yields*—Continued.

Species of wood.	Fermentation No.	Cook No.	Total reducing sugars (per cent of original dry wood).	Per cent of total reducing sugars.		Fermentation efficiency.	Alcohol in beer.		Per cent of total sugars obtained as alcohol.	Alcohol yields.			Remarks.
				Fermentable.	Nonfermentable.		Actual alcohol yield.	Theoretical alcohol yield.		Per cent of original dry wood.	Gallons of absolute per dry ton.	Gallons of 190-proof per dry ton, allowing 5 per cent distillation loss.	
Longleaf pine	27	67	23.06	74.70	25.30	100.57	2.681	2.666	38.40	8.855	26.78	26.73	
	28	67	23.06	73.50	26.50	92.66	2.379	2.567	34.78	8.021	24.26	24.22	
				73.32	26.67					8.282	25.05	24.97	Average.
	22	68	23.25	71.42	28.58	99.26	2.126	2.142	36.23	8.424	25.48	24.43	
	23	68	23.25	73.96	26.04	96.13	2.396	2.492	36.34	8.448	25.55	25.50	
	24	68	23.25	71.08	28.92	90.97	2.562	2.816	33.05	7.683	23.24	23.20	
	25	68	23.25	72.78	27.22	98.11	2.528	2.577	36.49	8.484	25.66	25.61	
	26	68	23.25	73.28	26.72	95.60	2.352	2.460	35.81	8.325	25.18	25.13	
	27	68	23.25	72.39	27.61	100.20	2.691	2.686	37.07	8.619	26.07	26.02	
	28	68	23.25	72.49	27.35	94.55	1.283	1.357	31.91	8.330	25.19	24.97	
				72.49	27.49					83.30	25.196	24.98	Do.
Lodgepole pine	25	69	21.93	66.42	33.58	99.19	2.507	2.527	33.68	7.385	22.34	22.30	
	26	69	21.93	67.26	32.74	95.75	2.609	2.725	32.92	7.219	21.84	21.79	
	27	69	21.93	66.99	33.01	92.59	2.219	2.397	31.71	6.953	21.03	20.99	
	28	69	21.93	67.64	32.36	93.78	1.943	2.072	32.42	7.183	21.73	21.69	
	29	69	21.93	68.58	31.42	94.77	2.373	2.504	33.22	7.285	22.03	21.99	
				67.37	33.66					7.205	21.79	21.75	Do.
Norway pine, extracted chips	25	70	25.62	67.52	32.48	77.74	2.014	2.591	26.83	6.873	20.79	20.75	
	26	70	25.62	65.12	34.88	91.78	2.421	2.638	30.55	7.827	23.67	23.63	
	27	70	25.62	68.02	31.98	95.83	1.940	2.024	33.32	8.536	25.82	25.77	
				66.88	33.10				30.23	7.745	23.42	23.38	Do.
Red spruce	26	71	22.06	71.23	28.77	99.35	2.949	2.968	39.29	8.668	26.22	26.17	
	27	71	22.06	72.84	27.16	98.22	2.624	2.671	36.57	8.067	24.40	24.35	
	28	71	22.06	72.84	27.16	91.29	2.366	2.592	33.98	7.497	22.68	22.63	
	29	71	22.06	75.76	24.24	91.80	2.073	1.258	35.54	7.841	23.72	23.67	

	30	71	22.06	72.94	27.06	98.05	2.752	2.807	36.55	8.063	24.39	24.34	
	31	71	22.06	71.13	28.87	98.94	2.786	2.816	35.97	7.934	24.00	23.95	
	32	71	22.06	72.00	28.00	93.95	2.709	2.884	34.57	7.626	23.07	23.02	
				72.67	27.32					7.956	24.06	24.01	Do.
Western larch	26	72	26.21	54.81	45.19	93.20	2.007	2.153	26.11	6.844	20.70	20.66	
	27	72	26.21	45.81	45.81	97.06	1.724	1.766	26.88	7.046	21.31	21.27	
	28	72	26.21	55.11	44.89	87.53	1.583	1.808	24.65	6.462	19.55	29.51	
	30	72	26.21	55.10	44.90	99.46	1.755	1.764	28.01	7.341	22.21	22.16	
	31	72	26.21	53.97	46.03	98.80	1.911	1.934	27.25	7.143	21.60	21.56	
	33	72	26.21	54.96	45.04	91.92	1.690	1.839	25.82	6.768	20.47	20.43	
	36	72	26.21	54.69	45.31					6.934	20.97	20.93	Do.
Hard maple	27	73	18.93	33.16	66.84	88.88	1.086	1.222	15.06	2.852	8.62	8.61	
	28	73	18.93	34.87	65.13	86.94	.988	1.136	15.49	2.933	8.87	8.85	
	29	73	18.93	36.31	63.69	92.07	1.118	1.214	17.09	3.234	9.78	9.76	
	30	73	18.93	34.12	65.88	94.95	1.103	1.162	16.56	3.135	9.48	9.46	
	31	73	18.93	32.94	67.06	91.94	1.008	1.096	15.48	2.930	8.86	8.85	
	32	73	18.93	32.88	67.12	97.29	.952	.978	16.35	3.095	9.36	9.34	
				34.04	65.95					3.029	9.16	9.14	Do.
Douglas fir, Washington	28	74	21.13	73.82	26.18	97.59	2.521	2,583	36.82	7.780	23.53	23.49	
	29	74	21.13	74.72	25.28	97.96	2.698	2.754	37.41	7.904	23.91	23.86	
	30	74	21.13	77.44	22.56	96.18	2.634	2.739	38.07	8.044	24.33	24.28	
	31	74	21.13	71.84	28.16	102.33	2.568	2.510	37.57	7.939	24.01	23.97	
	32	74	21.13	74.31	25.69	95.79	2.574	2.687	36.38	7.688	23.25	23.21	
	33	74	21.13	77.10	22.90	99.80	2.603	2.608	39.33	8.310	25.14	25.09	
	34	74	21.13	76.95	23.05	94.77	2.591	2.734	37.27	7.876	23.82	23.78	
				75.16	24.83					7.934	23.99	23.95	Do.
Silver maple	28	75	20.74	47.98	52.02	85.69	1.474	1.720	21.01	4.358	13.18	13.16	
	29	75	20.74	44.11	55.89	94.72	1.450	1.531	21.36	4.429	13.40	13.37	
	30	75	20.74	50.57	49.43	89.06	1.534	1.723	23.02	4.774	14.44	14.41	
	31	75	20.74	46.24	53.76	96.34	1.448	1.503	22.77	4.722	14.28	14.26	
	32	75	20.74	.....	.....	121.96	1.423	1.167	21.16	.....	.....	.....	
	33	75	20.74	47.24	52.76	100.34	1.140	1.136	24.23	5.025	15.20	15.17	
				47.12	52.77					4.661	14.10	14.07	Do.
Beech	29	76	21.24	23.09	76.91	81.61	.552	.713	9.63	2.045	6.19	6.18	
	30	76	21.24	26.10	73.90	77.78	.709	.912	10.38	2.204	6.67	6.65	
	31	76	21.24	19.48	80.52	94.46	.576	.610	9.40	1.997	6.04	6.03	
	32	76	21.24	20.22	79.78	78.99	.528	.668	8.16	1.734	5.25	5.23	
				22.22	77.77					1.995	6.03	6.02	Do.

TABLE 1.—*Sugar and alcohol yields*—Continued.

Species of wood.	Fermentation No.	Cook No.	Total reducing sugars (per cent of original dry wood.	Per cent of total reducing sugars.		Fermentation efficiency.	Alcohol in beer.		Per cent of total sugars obtained as alcohol.	Alcohol yields.			Remarks.
				Fermentable.	Nonfermentable.		Actual alcohol yield.	Theoretical alcohol yield.		Per cent of original dry wood.	Gallons of absolute per dry ton.	Gallons of 190-proof per dry ton, allowing 5 per cent distillation less.	
White oak	31	77	17.30	48.46	51.54	94.56	1.575	1.666	23.42	4.051	12.25	12.23	
	32	77	17.30	49.47	50.53	94.25	1.623	1.722	23.83	4.123	12.47	12.45	
	33	77	17.30	50.36	49.64	90.19	1.743	1.933	23.22	4.017	12.15	12.13	
	34	77	17.30	51.39	48.61	87.55	1.565	1.788	23.00	3.978	12.03	12.01	
	35x	77	17.30	51.84	48.16	88.09	1.426	1.619	23.34	4.038	12.21	12.19	
	34x	77	17.30	51.41	48.59	96.95	1.467	1.513	25.48	4.407	13.33	13.31	
				50.48	49.51					4.102	12.40	12.38	Average.
Red Oak	32	78	18.38	30.79	69.21	89.73	.971	1.082	14.12	2.595	7.85	7.84	
	33	78	18.38	29.07	70.93	90.91	.988	1.087	13.51	2.483	7.51	7.49	
	34	78	18.38	31.35	68.65	100.10	1.059	1.058	16.04	2.948	8.92	8.90	
				30.40	69.59					2.675	8.09	8.07	Do
Sycamore	32	79	18.30	37.35	62.65	83.26	0.973	1.169	15.89	2.908	8.80	8.78	
	33	79	18.30	37.42	62.58	94.59	1.070	1.131	18.09	3.311	10.01	10.00	
	34	79	18.30	37.88	62.12	88.56	1.039	1.173	17.15	3.138	9.49	9.47	
	35	79	18.30	41.30	58.70	83.31	1.148	1.378	17.88	3.218	9.73	9.72	
	36	79	18.30	40.35	59.65	91.46	.727	.795	18.86	3.452	10.44	10.42	
				38.86	61.14					3.205	9.69	9.67	Do.
Slippery elm	33	80	16.60	.....	.....	91.83	1.293	1.408	18.53	.....	.....	.....	
	34	80	16.60	28.65	71.35	82.39	.872	1.058	12.06	2.003	6.06	6.05	
	35	80	16.60	26.21	73.79	96.73	.919	.942	12.96	2.151	6.51	6.49	
	35y	80	16.60	29.24	70.76	94.22	.465	.494	14.08	2.338	7.07	7.06	
	34y	80	16.60	26.02	73.98	89.59	.635	.709	11.92	1.978	5.98	5.97	
	36	80	16.60	23.86	76.14	71.23	.616	.865	8.69	1.442	4.36	4.35	
				26.79	73.20					1.382	5.99	5.98	Do.
Red gum	33	81	20.42	38.41	61.59	85.45	1.190	1.393	16.78	3.426	10.36	10.34	
	34	81	20.42	39.17	60.83	94.25	1.336	1.418	18.87	3.853	11.65	11.63	

	35	81	20.42	38.97	61.03	96.56	1.390	1.439	19.24	3.928	11.88	11.86	
	36	81	20.42	38.70	61.30	84.55	.956	1.131	16.72	3.415	10.33	10.31	
				38.81	61.18					3.658	11.06	11.03	Do.
Cottonwood	36	82	18.19	29.78	70.22	99.89	.899	.900	15.21	2.766	8.37	8.35	
	37	82	18.19	28.67	71.33	86.00	.955	1.110	12.60	2.292	6.93	6.92	
	38	82	18.19	44.39	55.61	53.50	.888	1.660	12.14	2.208	6.68	6.66	
	39	82	18.19	31.26	68.74	80.84	.784	.970	12.92	2.350	7.11	7.09	
	40	82	18.19	30.21	69.79	83.44	.829	.994	12.88	2.343	7.09	7.07	
				32.86	67.13					2.392	7.23	7.21	Do.
Western larch	36	83	30.52	59.50	40.50	93.05	1.664	1.788	28.29	8.635	26.12	26.07	
	37	83	30.52	59.45	40.55	87.57	1.714	1.957	26.61	8.121	24.56	24.52	
	38	83	30.52	58.64	41.36	97.32	1.664	1.710	29.17	8.902	26.93	26.88	
	39	83	30.52	60.11	39.89	90.16	1.514	1.679	27.70	8.453	25.57	25.52	
	40	83	30.52	57.52	42.48	99.74	1.743	1.748	29.32	8.950	27.07	27.02	
	41	83	30.52	41.10	58.90	130.38	1.497	1.148	27.39	8.359	25.28	25.23	
	42	83	30.52	71.48	28.52	85.06	2.415	2.839	31.08	9.485	28.69	28.63	
	43	83	30.52	55.24	44.76	99.23	1.413	1,424	28.02	8.550	25.86	25.81	
				57.88	42.12					8.687	26.26	26.21	Do.
White spruce	36	84	22.11	69.03	30.97	94.08	1.886	2.005	33.19	7.338	22.20	22.16	
	37	84	22.11	72.64	27.36	88.09	2.597	2.948	32.70	7.231	21.87	21.83	
	38	84	22.11	68.83	31.17	92.03	2.333	2.535	32.38	7.158	21.65	21.61	
	39	84	22.11	67.82	32.18	97.34	2.553	2.623	33.74	7.460	22.57	22.52	
	41	84	22.11	73.61	26.39	97.35	1.642	1.687	36.62	8.098	24.49	24.45	
				70.38	29.63					7.457	22.55	22.51	Do
White spruce and bark (25.53 per cent bark)	37	85	22.49	63.42	36.58	89.54	1.704	1.903	29.02	6.528	19.74	19.71	
	38	85	22.49	58.42	41.58	89.39	2.310	2.584	26.69	6.003	18.16	18.12	
	39	85	22.49	58.78	41.22	93.67	2.385	2.546	28.14	6.328	19.14	19.10	
	40	85	22.49	59.55	40.45	96.39	2.591	2.688	29.34	6.598	19.96	19.92	
	41	85	22.49	.....	.....	158.50	2.842	1.793	38.63	.....	.....	.....	
				60.04	39.98					6.364	19.25	19.21	Do.
Western hemlock	38	86	21.15	77.48	22.52	86.95	2.175	2.502	34.43	7.282	22.03	21.98	
	39	86	21.15	77.73	22.27	92.54	2.716	2.935	36.76	7.776	23.52	23.47	
	40	86	21.15	77.70	22.30	92.99	2.500	2.691	36.93	7.810	23.62	23.58	
	41	86	21.15	.....	.....	66.22	2.785	4.206	28.02	.....	.....	.....	
				77.63	22.36					7.622	23.05	23.01	Do.

TABLE 1.—*Sugar and alcohol yields*—Continued.

Species of wood.	Fermentation No.	Cook No.	Total reducing sugars (per cent of original dry wood).	Per cent of total reducing sugars.		Fermentation efficiency.	Alcohol in beer.		Per cent of total sugars obtained as alcohol.	Alcohol yields.			Remarks.
				Fermentable.	Nonfermentable.		Actual alcohol yield.	Theoretical alcohol yield.		Per cent of original dry wood.	Gallons of absolute per dry ton.	Gallons of 190-proof per dry ton, allowing 5 per cent distillation loss.	
White spruce and bark. Bark, 8.49 per cent of total.	38	87	19.60	72.22	27.78	95.08	2.532	2.663	35.10	6.879	20.81	20.77	
	39	87	19.60	71.47	28.53	96.90	2.615	2.699	35.40	6.938	20.98	20.94	
	40	87	19.60	66.77	33.23	120.72	2.407	1.994	41.20	8.075	24.42	24.38	
	41	87	19.60	70.14	29.86	90.27	2.493	2.762	32.36	6.343	19.19	19.15	
	42	87	19.60	66.78	33.22	83.59	1.651	1.975	28.53	5.592	16.91	16.88	
				69.47	30.52					6.765	20.46	20.42	Average.
White spruce bark	39	88	17.07	36.00	64.00	82.10	1.231	1.499	15.11	2.579	7.80	7.79	
	40	88	17.07	27.91	72.09	118.31	1.106	.935	16.88	2.881	8.71	8.70	
				31.95	68.04					27.30	8.25	8.24	Do.
White spruce (2.5 per cent HCl)	40	89	17.02	5.10	94.90	173.71	.171	.098	4.53	.771	2.33	2.33	
	41	89	17.02	.95	99.05	412.58	.128	.031	2.00	.341	1.03	1.03	
	42	89	17.02	(2)	(2)	.....	.056	.....	.....	.....	.....	.....	
				3.02	96.97					5.56	1.68	1.68	Do.
White spruce (1.8 per cent HCl)	41	90	19.69	1.79	98.21	.....	.....	.080	.....	.....	.....	.....	
	42	90	19.69	(2)	(2)	.....	.147	.....	.....	.....	.....	.....	
	43	90	19.69	(2)	(2)	.....	.152	.....	.....	.....	.....	.....	
Spruce (1.8 per cent $H_2SO_4+NaCl=NaHSO_4$)	42	92	20.44	4.06	95.94	504.46	.790	.157	(2)	.....	.....	.....	
	43	92	20.44	5.22	94.78	158.40	.324	.204	4.222	.863	2.61	2.60	
	44	92	20.44	9.55	90.45	65.09	.223	.343	3.18	.650	1.97	1.96	
	45	92	20.44	11.22	88.78	70.80	.282	.398	4.06	.830	2.51	2.50	
	46	92	20.44	32.43	67.57	197.10	2.24	1.136	32.67	6.677	20.20	20.16	
				12.49	87.50					2.255	6.32	6.58	Do.
Spruce (1.8 per cent HCl neut. with $CaCO_3$)	42	93	18.25	7.78	92.22	.....	.....	.....	.....	.....	.....	.....	
	44	93	18.25	.105	99.895	598.00	.0571	.0096	(3)	.....	.....	.....	
	45	93	18.25	.50	99.50	257.15	.0552	.021	.66	.120	.36	.36	

	46	93	18.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	55	93	18.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Spruce (1.8 per cent H_2SO_4+NaCl=Na_2SO neut. with $CaCl_2$)	42	94	19.44	24.91	75.09	61.92	.522	.843	7.882	1.532	4.64	4.63	
	43	94	19.44	.....	.....	.....	.584	.....	.....	.....	.....	.....	
	44	94	19.44	14.82	95.18	68.79	.331	.481	5.21	1.013	3.06	3.06	
	45	94	19.44	10.45	89.55	135.70	.449	.331	7.25	1.409	4.26	4.26	
				12.63	87.86					1.211	3.66	3.66	Do.
Spruce(2 per cent Cl2$KClO_3$+H_2SO_4+10HCl = K_2SO_4+6Cl_2+6H_2O).	42	95	19.59	5.31	94.69	190.56	.247	.130	5.176	1.014	3.07	3.06	
	43	95	19.59	7.51	92.49	188.33	.334	.177	7.227	1.416	4.28	4.27	
	44	95	19.59	6.05	63.95	159.03	.228	.143	4.92	.963	2.91	2.91	
	45	95	19.59	1.75	98.25	64.39	.0284	.044	.58	.113	.34	.34	
	46	95	19.59	7.82	92.18	66.24	.123	.1858	2.62	.511	2.65	2.64	
	53	95	19.59	44.30	55.68	2.962	.067	2.262	.608	8.032	.....	.....	
	54	95	19.59	12.12	82.87	.....	.....	.....	.....	.....	.....	.....	
	.....	95	19.59	(4)	.....	.....	.....	.....	.....	.....	.....	.....	
	55	95	19.59	(4)	.....	.....	.....	.....	.....	.....	.....	.....	
Spruce (1.8 per cent H_2SO_4+$\frac{1}{10}$ amt. of $KClO_3$ to make 2 $KClO_3$+1+2SO_4= 2$HClO_3$+K_2SO_4).	43	96	120.34	.31	99.69	1,849.40	.....	.....	.....	.....	.....	.....	
	44	96	20.34	65.49	34.51	78.05	2.145	2.748	26.12	5.314	16.07	16.04	
	46	96	120.34	69.52	30.48	89.78	2.356	2.624	31.90	6.488	19.62	19.59	
				45.10	54.89					5.901	17.84	17.81	Do.
Spruce (1.8 per cent H_2SO_4+$\frac{1}{2}$ $KClO_3$ to make 2 $KClO_3$+H_2SO_4= $HClO_3$).	44	97	21.45	60.63	39.37	89.70	2.182	2.432	27.80	5.963	18.04	18.00	
	45	97	21.45	48.53	51.47	104.62	2.029	1.939	25.95	5.566	16.84	16.80	
	46	97	21.45	65.99	34.01	82.46	1.890	2.292	27.81	5.966	18.04	18.01	
	49	97	21.45	65.71	34.29	88.88	2.199	2.470	29.80	6.40	.....	.....	
	50	97	21.45	90.00	91.00	.....	.366	.....	.....	.....	.....	.....	
	51	97	21.45	68.82	31.18	84.35	2.185	2.590	29.54	6.34	.....	.....	
	52	97	21.45	64.52	35.48	99.75	2.203	2.221	32.90	7.075	.....	.....	
	53	97	21.45	30.34	69.66	365.00	2.460	.692	.....	.....	.....	.....	
	54	97	21.45	69.25	32.75	87.75	1.646	1.881	55.00	1.182	.....	.....	
				62.64	46.58					3.855	17.30	17.60	Do.
Residue from (cook No. 95+2.5 per cent H_2SO_4).	.....	98	6.56	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Sugar pine (Green 58.06 and H_2O 2.5 per cent H_2SO_4 150 per cent H_2O).	[5] 45	99	18.03	.....	.....	115.94	2.472	2.132	36.62	.....	.....	.....	
	46	99	18.03	72.62	27.38	97.36	2.482	2.549	36.14	6.516	19.71	19.67	
	49	99	18.03	73.75	26.25	86.00	1.989	2.317	32.35	5.835	17.63	17.59	
	50	99	18.03	71.30	28.70	98.75	2.268	2.300	35.90	6.470	19.56	19.53	
				72.55	27.45					6.276	18.96	18.93	Do.

[3] Final sugar higher than original. [3] Over 100. [4] More sugar in beer. [5] This fermentation was valueless on account of being chilled.

TABLE 1.—*Sugar and alcohol yields*—Continued.

Species of wood.	Fermentation No.	Cook No.	Total reducing sugars (per cent of original dry wood).	Per cent of total reducing sugars.		Fermentation efficiency.	Alcohol in beer.		Per cent of total sugars obtained as alcohol.	Alcohol yields.			Remarks.
				Fermentable.	Nonfermentable.		Actual alcohol yield.	Theoretical alcohol yield.		Per cent of original dry wood.	Gallons of absolute per dry ton.	Gallons of 190-proof per dry ton, allowing 5 per cent distillation loss.	
Spruce (1.8 per cent H_2SO_4, 0.1 per cent H_3PO_4, 125 per cent H_2O).	[5] 45	100	21.12	57.93	42.07	118.55	2.785	2.349	35.10	7.413	22.42	22.38	
	46	100	21.12	68.10	31.90	92.24	2.44	2.642	32.14	6.788	20.53	20.49	
	49	100	21.12	69.45	98.00	.....	2.869	2.950	34.65	7.320	22.14	22.09	
	50	100	21.12	69.10	30.90	106.08	2.745	2.590	37.31	7.835	23.69	23.65	
	51	100	21.12	51.40	48.60	177.4	2.537	1.430	46.60	9.850	29.79	29.73	
	52	100	21.12	66.15	33.85	98.00	2.482	2.508	33.38	7.085	21.43	21.38	
	53	100	21.12	63.50	36.50	112.7	3.366	2.990	37.58	7.900	22.89	31.20	
	54	100	21.12	69.00	31.00	102.80	2.383	2.320	36.18	7.620	23.04	22.97	
				64.32	44.10					7.726	23.24	24.23	Average.
Spruce (0.9 per cent H_2SO_4 0.9 per cent H_3PO_4).	49	101	20.83	61.11	38.89	96.50	2.551	2.643	30.10	6.280	18.99	18.95	
	50	101	20.83	.....	.....	78.98	2.368	1.870	19.14	.....	.....	.....	
	51	101	20.83	57.80	42.20	90.35	2.241	2.481	26.65	5.53	16.72	16.69	
	52	101	20.83	58.70	41.30	100.5	2.156	2.144	30.00	6.256	18.92	18.88	
	53	101	20.83	55.35	44.75	111.80	3.049	2.730	31.52	6.650	20.01	20.07	
	54	101	20.83	56.10	43.90	111.95	3.197	2.860	32.00	6.660	20.14	20.10	
	55	101	20.83	42.25	57.75	164.8	3.478	2.109	35.49	7.413	22.42	22.38	
				55.20	44.79					5.635	19.65	19.62	Do.
Spruce (1.8 per cent H_3PO_4)	49	102	19.38	53.75	46.25	9.175	2.286	2.498	25.10	4.87	14.73	14.70	
	50	102	19.38	51.70	48.30	104.0	2.368	2.280	27.40	5.32	16.09	16.06	
	51	102	19.38	56.65	43.35	86.7	2.355	2.710	25.14	4.86	14.70	14.67	
	52	102	19.38	46.52	53.48	122.3	2.849	2.330	28.05	5.64	17.05	17.02	
	53	102	19.38	50.05	49.95	104.0	2.545	2.445	26.70	5.15	15.57	15.54	
	54	102	19.38	50.85	49.15	104.9	2.676	2.548	27.28	5.29	16.00	15.97	
				51.58	44.74					5.18	15.69	15.66	Do.
Sugar pine (18 per cent H_2SO_4)	49	103	20.23	72.60	27.40	96.7	2.255	2.333	35.81	7.244	21.91	21.86	
	50	103	([6])	.....	.....	84.0	2.521	3.001	27.45	.....	.....	.....	
	51	103	([6])	70.85	79.15	96.3	2.004	2.082	34.78	7.036	21.28	21.24	
	52	103	([6])	51.35	48.65	136.8	2.306	1.688	35.80	7.242	21.90	21.86	

	53	103	(6)	69.20	30.80	100.1	2.416	2.413	35.24	7.139	21.59	21.55	
	54	103	(6)	71.45	28.55	94.1	2.402	2.558	34.30	6.939	20.98	20.94	
	55	103	(6)	63.50	36.50	108.3	3.195	2.945	35.05	7.091	21.44	21.40	
				66.49	33.51					7.115	21.51	21.47	Do.
Spruce (1.80 per cent H_2SO_4, 0.10 per cent $FeSO_4$).	49	104	21.40	62.68	37.32	101.00	2.802	2.778	32.25	6.910	20.92	20.86	
	50	104	21.40	.....	.....	186.7	3.107	1.665	32.08	.....	20.82	20.68	
	51	104	21.40	63.72	36.28	101.50	2.630	2.586	33.00	7.052	21.33	23.89	
	52	104	21.40	.....	.....	80.75	2.641	3.272	31.95	.....	.....	.....	
	53	104	21.40	.....	.....	90.85	2.179	2.400	25.66	.....	.....	.....	
	54	104	21.40	64.15	35.85	100.2	2.916	2.900	32.79	7.015	21.21	21.17	
	55	104	21.40	62.35	37.65	100.0	2.674	2.672	31.81	6.805	20.58	20.54	
				63.23	36.77					6.927	20.97	21.42	Do.
Spruce	51	107	17.93	61.50	38.50	105.20	1.699	1.615	33.00	5.865	17.73	17.70	
	52	107	(7)	58.76	41.24	111.8	1.677	1.500	29.50	5.300	16.03	16.00	
				60.13	39.87					5.583	16.89	16.85	Do.
Spruce (0.9 per cent H_2SO_4, 0.9 per cent niter cake).	51	108	.....	59.50	.....	86.80	2.166	2.500	25.00	4.800	14.51	14.79	
	52	108	.....	56.84	.....	103.4	2.365	2.290	30.00	5.765	17.43	17.40	
	53	108	.....	60.50	.....	70.95	2.115	2.842	21.92	4.220	12.86	12.74	
	54	108	.....	59.80	40.20	94.00	2.330	2.482	28.70	5.522	16.70	16.67	
	55	108	.....	59.18	40.82	.....	4.585	.....	1.64	5.077	15.38	15.34	

[6] Recalculate alcohol yields.
[7] Niter cake with H_2SO_4 equivalent of 18 per cent used to 19.25 make 1.8 H_2SO_4.

TABLE 2.—*Acid yields.*

Cook.	Acetic acid (per cent of original dry wood).	Formic acid (per cent of original dry wood).	Ratio of acetic acid to formic acid.	Per cent of tota. volatile acid in blow-off.		Remarks.
				Acetic.	Formic.	
21	1.52	0.239	6.36 to 1	9.24	9.00	Data not complete.
22						
23	2.27	.540	4.20 to 1	7.54	8.70	Blow-off open.
24	2.39	.059	40.40 to 1			Do.
25	1.77	.337	5.25 to 1			
26	1.75	.431	4.07 to 1	5.22	9.95	Do.
27	1.29	.171	7.55 to 1			Data not complete.
28						
29	1.29	.310	4.16 to 1	5.78	4.94	
30	1.38	.642	2.15 to 1	11.70	12.27	
31	1.755	.572	3.05 to 1	8.53	14.23	
32	1.67	1.090	1.53 to 1	11.48	10.64	
33	1.457	.355	4.10 to 1	12.65	6.01	
34	2.11	.480	4.40 to 1	7.91	24.55	
35	1.05	.443	2.37 to 1	16.30	4.49	
36	2.43	.735	3.31 to 1	6.80	16.28	
37	1.43	.253	5.65 to 1	10.75	3.82	
38	.87	.430	2.02 to 1	7.48	.47	
39	1.33	.056	23.75 to 1			Blow-off open.
40	1.56	.470	3.32 to 1	11.68	8.14	
41	1.416	.430	3.30 to 1	8.24	13.50	
42	1.55	.570	2.72 to 1	12.25	12.80	
43	1.51	.160	9.44 to 1	11.80	23.40	
44	1.69	.290	5.82 to 1	8.80	9.40	
45	1.67	.790	2.11 to 1	9.48	8.26	
46	2.36	1.450	1.63 to 1	9.45	9.75	
47	2.62	.340	7.71 to 1	9.03	12.32	
48	2.97	.469	6.33 to 1	5.19	3.55	
49	1.97	.230	8.57 to 1	7.59	18.48	
50	1.715	.254	6.75 to 1	5.26	1.74	
51						Data not complete.
52						Do.
53						Do.
54						Do.
55	2.14	.440	4.86 to 1	13.01	23.18	
56	2.915	1.492	1.95 to 1	7.32	3.88	
57	3.53	.659	5.36 to 1	7.69	14.79	
58	2.47	.399	6.19 to 1	7.84	6.28	
59	2.16	.869	2.49 to 1	10.23	8.91	
60						Do.
61	3.34	.933	3.58 to 1	7.39	5.45	
62	4.70	.706	6.66 to 1	15.53	4.09	Birch.
63	2.96	.846	3.50 to 1	8.09	11.82	White pine, Idaho.
64	2.70	1.08	2.50 to 1	9.06	5.93	Red spruce.
65	2.24	1.42	1.58 to 1	6.45	7.75	Douglas fir, Montana.
66	2.68	.626	4.28 to 1	14.87	29.75	White pine.
67	2.60	1.44	1.80 to 1	8.53	6.95	Longleaf pine.
68	2.47	1.18	2.09 to 1	18.11	7.38	Do.
69	2.84	.447	7.34 to 1	6.76	3.25	Lodgepole pine.
70	1.76	1.19	1.48 to 1	7.53	2.32	Norway pine.
71	2.75	1.18	2.33 to 1	8.92	6.59	Red spruce.
72	2.84	1.46	1.945 to 1	7.72	9.31	Western larch.
73	3.77	.512	7.36 to 1	12.52	4.26	Hard maple.
74	2.19	.962	2.28 to 1	7.92	8.15	Douglas fir, Washington.
75	1.09	.079	13.80 to 1	49.7	20.3	Silver maple.
76	4.80	.445	10.75 to 1	15.65	2.51	Beech.
77	2.57	.789	3.26 to 1	2.84	1.77	White oak.
78	3.98	.180	22.1 to 1	11.55	10.9	Red oak.
79	5.65	.634	8.91 to 1	10.48	4.09	Sycamore.
80	4.04	.738	5.48 to 1	11.02	9.42	Slippery elm.
81	4.18	.700	5.97 to 1	7.66	6.30	Red gum.
82	2.82	.406	6.94 to 1	7.79	26.90	Cottonwood.
83	1.90	.667	2.83 to 1	14.24	6.62	White spruce.
86	2.14	1.59	1.35 to 1	9.63	7.14	Western hemlock.

TABLE 3.—*Fermentation record.*

Fermentation No.	Cook No.	Yeast. Seed yeast. Brix.	Yeast. Seed yeast. Acidity.	Yeast. 96-hour yeast. Sp. gr. at 15° C.	Yeast. 96-hour yeast. Alcohol (per cent by weight).	Yeast. 96-hour yeast. Acidity.	Fermenter set. Date.	Fermenter set. Hour.	Hours filling fermenter.	Hours fermenting, including time of filling.	Mash before fermentation. Sp. gr. at 15° C.	Mash before fermentation. Reducing sugars (grams per liter).	Mash before fermentation. Acidity.	Mash before fermentation. Total solids (per cent).	Mash before fermentation. Brix.	Brix record (decrease in Brix). First day.	Brix record. Second day.	Brix record. Third day.	Brix record. Fourth day.	Brix record. Fifth day.	Attenuation (degrees).	Beer. Brix fourth day.	Beer. Distillation. Date.	Beer. Distillation. Hour.	Beer. Reducing sugars (grams per liter).	Beer. Sp. gr. at 15° C.	Beer. Acidity.	Beer. Total solids (per cent by weight).	Beer. Alcohol (per cent by weight).
								a. m.																*a. m.*					
1	21	....	....	....	....	....	Sept. 13, 1914	10.00	32.5	128.5	1.0486	82.16	8.0	.....	11.9	4.3	0.4	0.1	0.2	0.0	5.0	6.9	Sept. 18, 1914	10.00	36.50	1.0254	10.2	.....	1.818
4	21	....	....	1.0208	5.672	14.8	Oct. 14, 1914	9.00	32.5	128.5	1.0293	50.76	2.8	.....	7.5	2.6	.1	.3	.0	.1	3.0	4.5	Oct. 19, 1914	9.00	22.46	1.0160	6.4	.....	1.452
4	22	....	....	1.0208	5.672	14.8	Oct. 14, 1914	9.00	32.5	128.5	1.0151	22.46	2.0	.....	4.1	.8	.5	.2	.0	.0	1.6	2.5	Oct. 19, 1914	9.00	7.49	1.0086	4.7	.....	0.783
1	22	....	....	....	....	....	Sept. 13, 1914	10.00	32.5	128.5	1.0476	82.58	5.0	.....	11.7	4.3	.4	.1	.0	.2	4.8	6.9	Sept. 18, 1914	10.00	35.92	1.0266	9.6	.....	2.271
14	22	....	....	1.0235	5.784	24.5	Mar. 18, 1915	9.15	32.5	128.5	1.0551	94.86	8.0	.....	13.6	4.6	1.0	.1	.2	.....	5.9	7.7	Mar. 23, 1915	9.15	41.72	1.0314	13.2	.....	2.443
1	23	....	....	....	....	....	Sept. 13, 1914	10.00	32.5	128.5	1.0489	79.58	8.8	.....	12.2	4.1	.6	.1	.1	.2	4.9	7.3	Sept. 18, 1914	10.00	35.70	1.0278	14.4	.....	2.128
5	23	....	....	1.0203	5.616	14.0	Oct. 21, 1914	9.00	32.5	128.5	1.0483	80.66	8.8	.....	11.6	4.0	.4	+.1	−.1	.0	4.4	7.2	Oct. 26, 1914	9.00	35.48	1.0269	12.4	.....	2.045
1	24	....	....	....	....	....	Sept. 13, 1914	10.00	32.5	128.5	1.0470	74.06	10.4	.....	11.6	3.8	.3	.1	.1	.1	4.3	7.3	Sept. 18, 1914	10.00	34.56	1.0277	15.7	.....	1.778
5	24	....	....	1.0203	5.616	14.0	Oct. 21, 1914	9.00	32.5	128.5	1.0540	86.27	12.0	.....	13.1	4.6	.1	.1	.1	.1	4.9	8.2	Oct. 26, 1914	9.00	39.48	1.0320	16.0	.....	2.364
14	24	....	....	1.0235	5.784	24.5	Mar. 18, 1915	9.15	32.5	128.5	1.0461	73.94	9.6	.....	11.4	4.1	.3	.0	.0	.....	4.4	7.0	Mar. 23, 1915	9.15	33.58	1.0276	15.6	.....	1.849
1	25	....	....	....	....	....	Sept. 13, 1914	10.00	32.5	128.5	1.0486	85.064	4.6	.....	11.9	4.2	.4	.2	.1	.0	4.9	7.0	Sept. 18, 1914	10.00	34.80	1.0261	9.6	.....	2.340
5	25	....	....	1.0203	5.616	14.0	Oct. 21, 1914	9.00	32.5	128.5	1.0479	82.98	4.7	.....	11.5	3.8	.6	.2	.1	.1	4.7	6.8	Oct. 26, 1914	9.00	36.74	1.0253	7.6	.....	2.180
14	25	....	....	1.0235	5.784	24.5	Mar. 18, 1915	9.15	32.5	128.5	1.0470	80.75	6.0	.....	11.5	4.3	.5	.1	.0	.....	4.9	6.6	Mar. 23, 1915	9.15	35.66	1.0260	11.2	.....	2.115
1	26	....	....	....	....	....	Sept. 13, 1914	10.00	32.5	128.5	1.0470	81.43	7.6	.....	11.5	4.5	.1	.2	+.1	−.1	4.7	6.8	Sept. 18, 1914	10.00	33.36	1.0254	11.6	.....	2.141
5	26	....	....	1.0203	5.616	14.0	Oct. 21, 1914	9.00	32.5	128.5	1.0559	90.76	6.8	.....	13.5	4.1	.8	.0	.0	.2	4.9	8.6	Oct. 26, 1914	9.00	41.04	1.0329	4.8	.....	2.314
15	26	14.7	....	1.0224	6.113	17.4	Mar. 26, 1915	9.15	32.5	128.5	1.0506	85.80	8.9	.....	12.1	4.2	.7	.1	.1	.....	5.1	7.0	Mar. 31, 1915	9.15	36.44	1.0282	10.8	.....	2.334
1	27	....	....	....	....	....	Sept. 13, 1914	10.00	32.5	128.5	1.0453	71.84	5.2	.....	11.0	3.8	.3	.1	.1	.0	4.3	6.7	Sept. 18, 1914	10.00	30.88	1.0259	10.4	.....	1.811
5	27	....	....	1.0203	5.616	14.0	Oct. 21, 1914	9.00	32.5	128.5	1.0550	87.94	6.0	.....	13.2	4.0	.6	.1	.0	.1	4.7	8.5	Oct. 26, 1914	9.00	39.40	1.0332	8.8	.....	2.400
1	28	....	....	....	....	....	Sept. 13, 1914	10.00	32.5	128.5	1.0283	27.90	1.2	.....	7.4	.7	.1	.0	.2	.0	1.0	6.4	Sept. 18, 1914	10.00	18.82	1.0246	4.6	.....	0.453
1	29	....	....	....	....	....	Sept. 13, 1914	10.00	32.5	128.5	1.0386	63.42	3.6	.....	9.9	3.2	.3	.1	.1	.1	3.7	6.2	Sept. 18, 1914	10.00	27.18	1.0237	7.0	.....	1.494
2	29	12.0	....	....	....	....	Sept. 24, 1914	9.30	32.5	128.5	1.0511	87.28	4.0	.....	12.2	3.6	.5	.0	.0	.....	4.1	8.1	Sept. 29, 1914	9.30	39.52	1.0308	7.2	.....	2.008
15	29	14.7	....	1.0224	6.113	17.4	Mar. 26, 1915	9.15	32.5	128.5	1.0306	45.14	3.5	.....	7.8	2.3	.2	.2	.2	.....	2.9	4.9	Mar. 31, 1915	9.15	20.92	1.0195	13.8	.....	1.265
1	30	....	....	....	....	....	Sept. 13, 1914	10.00	32.5	128.5	1.0495	60.20	4.8	.....	9.1	3.0	.2	.0	.1	.0	3.3	5.8	Sept. 18, 1914	10.00	23.40	1.0221	9.6	.....	1.619
4	30	....	....	1.0208	5.762	14.8	Oct. 14, 1914	9.00	32.5	128.5	1.0477	74.04	6.3	.....	11.7	3.6	.9	.2	.0	.1	4.7	7.0	Oct. 19, 1914	9.00	28.12	1.0272	11.0	.....	2.322
1	31	....	....	....	....	....	Sept. 13, 1914	10.00	32.5	128.5	1.0444	69.28	3.8	.....	10.9	3.7	.9	.1	.1	.1	4.8	6.1	Sept. 18, 1914	10.00	24.74	1.0235	8.4	.....	2.189
4	31	....	....	1.0208	5.672	14.8	Oct. 14, 1914	9.00	32.5	128.5	1.0500	77.84	4.4	.....	11.9	1.6	1.4	.1	.1	.1	3.2	8.7	Oct. 19, 1914	9.00	44.17	1.0342	9.2	.....	1.586
6	31	....	....	1.0202	5.533	12.8	Nov. 4, 1914	9.00	32.5	128.5	1.0497	77.94	6.0	.....	11.9	2.9	1.6	.4	.1	.0	5.0	6.9	Nov. 9, 1914	9.00	27.62	1.0265	9.8	.....	2.299
1	32	....	....	....	....	....	Sept. 13, 1914	10.00	32.5	128.5	1.0447	64.36	5.0	.....	11.0	3.0	1.2	.5	.3	.0	5.0	6.0	Sept. 18, 1914	10.00	19.26	1.0235	11.0	.....	2.169
4	32	....	....	1.0208	5.672	14.8	Oct. 14, 1914	9.00	32.5	128.5	1.0447	64.04	4.5	.....	10.8	1.8	.1	.2	.1	.0	2.2	8.6	Oct. 19, 1914	9.00	39.00	1.0361	9.8	.....	1.153
6	32	....	....	1.0202	5.533	12.8	Nov. 4, 1914	9.00	32.5	128.5	1.0490	70.10	6.2	.....	11.7	0.5	1.7	.6	.4	.1	3.2	8.5	Nov. 9, 1914	9.00	28.34	1.0336	13.0	.....	2.956
11	32	....	22.0	1.0262	5.398	26.4	Feb. 11, 1915	9.15	32.5	128.5	1.0441	62.58	6.4	.....	11.6	4.3	1.1	.0	.2	.....	5.6	6.0	Feb. 16, 1915	9.15	18.34	1.0242	11.2	.....	2.016

TABLE 3.—*Fermentation record*—Continued.

Fermentation No.	Cook No.	Yeast. Seed yeast. Brix.	Yeast. Seed yeast. Acidity.	Yeast. 96-hour yeast. Sp. gr. at 15° C.	Yeast. 96-hour yeast. Alcohol (per cent by weight).	Yeast. 96-hour yeast. Acidity.	Fermenter set. Date.	Fermenter set. Hour.	Hours filling fermenter.	Hours fermenting, including time of filling.	Mash before fermentation. Sp. gr. at 15° C.	Mash before fermentation. Reducing sugars (grams per liter).	Mash before fermentation. Acidity.	Mash before fermentation. Total solids (per cent).	Mash before fermentation. Brix.	Brix record (decrease in Brix). First day.	Brix record. Second day.	Brix record. Third day.	Brix record. Fourth day.	Brix record. Fifth day.	Attenuation (degrees).	Beer. Brix fourth day.	Beer. Distillation. Date.	Beer. Distillation. Hour.	Beer. Reducing sugars (grams per liter).	Beer. Sp. gr. at 15° C.	Beer. Acidity.	Beer. Total solids (per cent by weight).	Beer. Alcohol (per cent by weight).
								a. m.																*a. m.*					
2	33	12.0	....	.....	.....	....	Sept. 24, 1914	9.30	32.5	128.5	1.0598	102.74	5.3	.....	14.5	3.9	1.4	0.3	0.0	.....	5.5	8.9	Sept. 29, 1914	9.30	45.65	1.0340	8.7	.....	3.066
3	33	....	....	1.0209	5.867	14.0	Oct. 7, 1914	9.00	32.5	128.5	1.0516	88.72	5.0	.....	12.6	3.5	1.2	.2	.0	.....	4.9	7.6	Oct. 12, 1914	9.00	40.06	1.0296	9.6	.....	2.409
2	34	12.0	....	.....	.....	....	Sept. 24, 1914	9.30	32.5	128.5	1.0583	100.56	4.4	.....	14.1	3.8	1.5	.3	.0	.....	5.7	8.4	Sept. 29, 1914	9.30	40.14	1.0323	8.4	.....	2.243
3	34	....	....	1.0209	5.867	14.0	Oct. 7, 1914	9.00	32.5	128.5	1.0529	89.92	4.8	.....	13.0	2.9	1.4	.4	.1	.....	4.8	8.2	Oct. 12, 1914	9.00	40.92	1.0319	10.2	.....	3.348
15	34	14.7	....	1.0224	6.113	17.4	Mar. 26, 1915	9.15	32.5	128.5	1.0499	81.92	6.0	.....	12.2	4.3	1.0	.0	.1	.....	5.4	6.8	Mar. 31, 1915	9.15	32.48	1.0271	6.8	.....	2.463
2	36	12.0	....	.....	.....	....	Sept. 24, 1914	9.30	32.5	128.5	1.0552	76.08	5.4	.....	13.4	3.2	1.3	.2	.1	.....	4.8	8.6	Sept. 29, 1914	9.30	25.56	1.0340	10.3	.....	2.316
3	36	....	....	1.0209	5.867	14.0	Oct. 7, 1914	9.00	32.5	128.5	1.0492	64.84	4.8	.....	11.9	2.1	1.1	.2	.0	.....	4.4	7.5	Oct. 12, 1914	9.00	19.70	1.0290	10.2	.....	2.114
11	36	....	22.0	1.0262	5.398	26.4	Feb. 11, 1915	9.15	32.5	128.5	1.0450	57.42	5.8	.....	11.0	3.1	.9	.1	.2	.....	4.3	6.7	Feb. 16, 1915	9.15	19.68	1.0278	10.0	.....	1.824
2	35	12.0	....	.....	.....	....	Sept. 24, 1914	9.30	32.5	128.5	1.0629	115.76	4.0	.....	15.2	4.7	1.4	.2	.0	.....	6.8	8.9	Sept. 29, 1914	9.30	49.52	1.0349	8.8	.....	3.348
3	35	....	....	1.0209	5.867	14.0	Oct. 7, 1914	9.00	32.5	128.5	1.0540	98.56	4.0	.....	13.2	3.6	1.3	.4	.0	.....	5.3	7.9	Oct. 12, 1914	9.00	41.64	1.0304	8.9	.....	2.737
2	37	12.0	....	.....	.....	....	Sept. 24, 1914	9.30	32.5	128.5	1.0632	116.37	3.4	.....	15.4	4.5	1.5	.2	.0	.....	6.2	9.2	Sept. 29, 1914	9.30	50.78	1.0360	8.4	.....	3.079
3	37	....	....	1.0209	5.867	14.0	Oct. 7, 1914	9.00	32.5	128.5	1.0508	89.44	2.0	.....	13.4	5.2	.9	.0	.0	.....	6.1	7.3	Oct. 12, 1914	9.00	37.41	1.0294	8.0	.....	2.336
15	37	14.7	....	1.0224	6.113	17.4	Mar. 26, 1915	9.15	32.5	128.5	1.0504	89.87	5.0	.....	12.4	4.4	.8	.2	.1	.....	5.5	6.9	Mar. 31, 1915	9.15	39.12	1.0278	8.8	.....	2.403
2	38	12.0	....	.....	.....	....	Sept. 24, 1914	9.30	32.5	128.5	1.0454	72.44	2.0	.....	11.2	3.4	.2	.0	.1	.....	3.7	8.5	Sept. 29, 1914	9.30	41.32	1.0335	6.2	.....	1.732
3	38	....	....	1.0209	5.867	14.0	Oct. 7, 1914	9.00	32.5	128.5	1.0479	68.92	1.8	.....	10.9	2.6	.2	.1	.0	.....	2.9	8.0	Oct. 12, 1914	9.00	37.56	1.0313	5.2	.....	1.673
7	38	....	....	1.0200	5.673	14.0	Nov. 11, 1914	9.00	32.5	128.5	1.0427	64.32	2.8	.....	11.0	2.6	.3	.1	.0	0.2	3.0	8.0	Nov. 16, 1914	9.00	36.66	1.0309	4.0	.....	1.382
2	39	12.0	....	.....	.....	....	Sept. 24, 1914	9.30	32.5	128.5	1.0585	100.54	2.2	.....	14.3	4.1	1.1	.1	.0	.....	5.3	9.0	Sept. 29, 1914	9.30	46.68	1.0353	6.0	.....	2.564
3	39	....	....	1.0209	5.867	14.0	Oct. 7, 1914	9.00	32.5	128.5	1.0446	75.08	2.8	.....	11.0	3.7	.4	.1	.1	.....	4.3	6.7	Oct. 12, 1914	9.00	32.42	1.0262	6.8	.....	1.923
15	39	14.7	....	1.0224	6.113	17.4	Mar. 26, 1915	9.15	32.5	128.5	1.0464	77.20	4.3	.....	11.4	3.7	.7	.0	.1	.....	4.5	6.9	Mar. 31, 1915	9.15	35.50	1.0278	7.2	.....	2.121
3	40	....	....	1.0209	5.867	14.0	Oct. 7, 1914	9.00	32.5	128.5	1.0546	98.36	3.6	.....	13.7	2.7	1.6	.7	.3	.....	5.3	8.4	Oct. 12, 1914	9.00	44.64	1.0332	8.2	.....	2.483
4	40	....	....	1.0208	5.672	14.8	Oct. 14, 1914	9.00	32.5	128.5	1.0491	83.34	3.2	.....	11.8	2.4	.2	.0	.0	.0	2.6	9.2	Oct. 19, 1914	9.00	54.38	1.0361	8.0	.....	1.501
15	40	14.7	....	1.0224	6.113	17.4	Mar. 26, 1915	9.15	32.5	128.5	1.0499	84.85	4.4	.....	12.3	3.7	1.3	.3	.1	.....	5.4	6.9	Mar. 31, 1914	9.15	30.30	1.0273	9.2	.....	2.424
4	41	....	....	1.0208	5.672	14.8	Oct. 14, 1914	9.00	32.5	128.5	1.0491	84.36	2.8	.....	11.7	2.1	.3	+.1	−.2	.0	2.6	9.1	Oct. 19, 1914	9.00	55.86	1.0362	6.0	.....	1.390
5	41	....	....	1.0203	5.616	14.0	Oct. 21, 1914	9.00	32.5	128.5	1.0518	87.67	4.2	.....	12.2	3.9	1.1	.2	0	.1	5.2	7.0	Oct. 26, 1914	9.00	36.66	1.0271	7.2	.....	2.415
6	41	....	....	1.0202	5.533	12.8	Nov. 4, 1914	9.00	32.5	128.5	1.0517	90.96	4.4	.....	12.5	3.0	1.6	.4	.2	.0	5.2	7.3	Nov. 9, 1914	9.00	38.42	1.0284	8.8	.....	2.397
7	41	....	....	1.0200	5.673	14.0	Nov. 11, 1914	9.00	32.5	128.5	1.0471	86.25	4.0	.....	11.5	2.5	.7	.4	.2	.0	3.8	7.7	Nov. 16, 1914	9.00	44.84	1.0310	4.4	.....	2.008
8	41	....	....	1.0234	6.088	16.0	Nov. 18, 1914	9.15	32.5	128.5	1.0570	98.18	4.0	.....	13.6	3.2	.7	.3	.2	.0	4.4	9.2	Nov. 23, 1914	9.15	52.52	1.0367	8.4	.....	2.199
4	42	....	....	1.0208	5.672	14.8	Oct. 14, 1914	9.00	32.5	128.5	1.0465	73.28	3.0	.....	10.9	1.4	.0	+.1	−.1	.1	1.4	9.5	Oct. 19, 1914	9.00	53.104	1.0371	7.8	.....	1.138
5	42	....	....	1.0203	5.616	14.0	Oct. 21, 1914	9.00	32.5	128.5	1.0480	78.62	3.6	.....	11.7	2.5	.3	.2	.1	.1	3.1	8.6	Oct. 26, 1914	9.00	46.38	1.0340	8.2	.....	1.533
6	42	....	....	1.0202	5.533	12.8	Nov. 4, 1914	9.00	32.5	128.5	1.0550	89.68	5.6	.....	13.1	2.6	1.5	.9	2	.2	5.2	7.7	Nov. 9, 1914	9.00	34.14	1.0297	9.2	.....	2.501
7	42	....	....	1.0200	5.673	14.0	Nov. 11, 1914	9.00	32.5	128.5	1.0503	81.82	5.0	.....	12.3	3.9	1.2	.3	.2	.1	5.6	6.7	Nov. 16, 1914	9.00	28.16	1.0207	5.6	.....	2.488

8	42	....	....	1.0234	6.088	16.0	Nov. 18, 1914	9.15	32.5	128.5	1.0504	81.28	5.6	.....	12.1	3.2	1.5	.4	.2	.0	5.3	6.8	Nov. 23, 1914	9.15	29.28	1.0270	10.0	.....	2.439
9	42	....	....	1.0235	6.067	15.5	Nov. 25, 1914	9.15	32.5	128.5	1.0587	96.88	5.6	.....	14.4	4.2	1.8	.6	.1	.0	6.7	7.7	Nov. 30, 1914	9.15	33.84	1.0310	10.8	.....	2.745
15	42	14.7	....	1.0224	6.113	17.4	Mar. 26, 1915	9.15	32.5	128.5	1.0489	44.144	6.6	.....	12.1	3.2	1.1	.6	.4	.0	5.3	6.8	Mar. 31, 1915	9.15	35.44	1.0271	10.7	.....	2.356
5	43	....	....	1.0203	5.616	14.0	Oct. 21, 1914	9.00	32.5	128.5	1.0456	78.04	3.6	.....	11.4	3.4	1.0	.2	.2	.0	4.8	6.6	Oct. 26, 1914	9.00	34.68	1.0275	6.8	.....	2.258
6	43	....	....	1.0218	5.604	12.0	Nov. 4, 1914	9.00	32.5	128.5	1.0460	79.10	3.2	.....	11.6	3.8	2.2	.0	.2	.0	5.2	6.4	Nov. 9, 1914	9.00	31.82	1.0250	6.6	.....	2.278
7	43	....	....	1.0195	5.660	13.0	Nov. 11, 1914	9.00	32.5	128.5	1.0492	85.50	4.6	.....	12.1	3.7	1.1	.3	.1	.1	5.2	6.9	Nov. 16, 1914	9.00	34.02	1.0208	8.8	.....	2.297
8	43	....	....	1.0234	6.088	16.0	Nov. 18, 1914	9.15	32.5	128.5	1.0470	79.32	3.6	.....	11.3	3.4	1.2	.2	.1	.1	4.9	6.4	Nov. 23, 1914	9.15	32.34	1.0256	8.8	.....	2.116
9	43	....	....	1.0235	6.067	15.5	Nov. 25, 1914	9.15	32.5	128.5	1.0584	101.16	6.0	.....	14.3	4.2	1.7	.3	.2	.0	5.4	7.9	Nov. 30, 1914	9.15	41.72	1.0320	10.0	.....	2.815
21	43	....	....	1.0223	6.143	16.0	June 18, 1915	9.15	32.5	128.5	1.0587	99.24	7.8	12.762	14.0	4.5	1.4	.5	+.1	.....	6.3	7.7	June 22, 1915	9.15	40.26	1.0310	13.2	7.578	2.720
6	44	....	....	1.0218	5.604	12.0	Nov. 4, 1914	9.00	32.5	128.5	1.0558	77.02	4.0	.....	13.4	3.2	1.7	.5	.2	.0	5.6	7.8	Nov. 9, 1914	9.00	42.18	1.0312	9.2	.....	2.589
7	44	....	....	1.0195	5.660	13.0	Nov. 11, 1914	9.00	32.5	128.5	1.0430	77.98	3.6	.....	10.6	3.7	.7	.1	.3	.1	4.8	5.8	Nov. 16, 1914	9.00	31.42	1.0229	6.4	.....	2.258
8	44	....	....	1.0234	6.088	16.0	Nov. 18, 1914	9.15	32.5	128.5	1.0507	89.26	3.4	.....	12.3	3.8	1.4	.2	.1	.0	5.5	6.8	Nov. 23, 1914	9.15	36.16	1.0273	8.0	.....	2.536
9	44	....	....	1.0235	6.067	15.5	Nov. 25, 1914	9.15	32.5	128.5	1.0569	101.69	4.8	.....	13.9	3.5	1.0	1.0	.5	.5	6.0	7.9	Nov. 30, 1914	9.15	45.44	1.0317	8.8	.....	2.752
6	45	....	....	1.0218	5.604	12.0	Nov. 4, 1914	9.00	32.5	128.5	1.0498	82.20	1.2	.....	12.2	3.2	1.6	.3	.2	.0	5.3	6.9	Nov. 9, 1914	9.00	29.90	1.0262	7.0	.....	2.319
7	45	....	....	1.0195	5.660	13.0	Nov. 11, 1914	9.00	32.5	128.5	1.0306	61.40	2.4	.....	9.6	2.3	.1	.2	.2	.2	2.8	6.8	Nov. 16, 1914	9.00	35.90	1.0268	8.0	.....	1.217
8	45	....	....	1.0222	5.958	15.0	Nov. 18, 1914	9.15	32.5	128.5	1.0508	84.68	2.4	.....	12.3	3.4	1.9	.1	.1	.0	5.5	6.8	Nov. 23, 1914	9.15	31.74	1.0270	8.8	.....	2.595
9	45	....	....	1.0235	6.067	15.5	Nov. 25, 1914	9.15	32.5	128.5	1.0558	92.40	4.0	.....	13.5	4.1	1.8	.1	.1	.0	6.1	7.4	Nov. 30, 1914	9.15	32.38	1.0295	8.8	.....	2.632
21	45	....	....	1.0223	6.143	16.0	June 18, 1915	9.15	32.5	128.5	1.0635	102.624	6.8	13.12	15.0	4.0	2.0	.5	.2	.....	6.7	8.3	June 22, 1915	9.15	37.80	1.0833	12.4	7.916	2.990
6	46	....	....	1.0218	5.604	12.0	Nov. 4, 1914	9.00	32.5	128.5	1.0535	72.72	5.4	.....	12.8	2.2	1.5	1.0	.5	.1	5.2	7.6	Nov. 9, 1914	9.00	20.68	1.0303	11.2	.....	2.548
7	46	....	....	1.0195	5.660	13.0	Nov. 11, 1914	9.00	32.5	128.5	1.0405	55.00	4.8	.....	10.4	1.8	.1	.1	.1	.1	2.1	8.3	Nov. 16, 1914	9.00	35.90	1.0327	8.6	.....	1.089
8	46	....	....	1.0222	5.958	15.0	Nov. 18, 1914	9.15	32.5	128.5	1.0476	64.384	4.4	.....	11.6	2.9	1.3	.4	.3	.0	4.9	6.7	Nov. 23, 1914	9.15	18.40	1.0257	12.8	.....	2.226
9	46	....	....	1.0234	5.843	16.4	Nov. 25, 1914	9.15	32.5	128.5	1.0469	63.10	2.5	.....	11.5	3.4	1.1	.4	.1	.3	5.0	6.5	Nov. 30, 1914	9.15	16.96	1.0257	12.0	.....	2.130
7	47	....	....	1.0200	5.673	14.0	Nov. 11, 1914	9.00	32.5	128.5	1.0479	73.744	2.0	.....	11.8	2.6	1.4	.7	.4	.2	5.1	6.5	Nov. 16, 1914	9.00	23.10	1.0261	7.3	.....	2.485
8	47	....	....	1.0222	5.958	15.0	Nov. 18, 1914	9.15	32.5	128.5	1.0525	75.88	2.6	.....	12.4	3.0	1.4	.6	.2	.1	5.2	7.2	Nov. 23, 1914	9.15	25.90	1.0276	8.4	.....	2.321
9	47	....	....	1.0234	5.843	16.4	Nov. 25, 1914	9.15	32.5	128.5	1.0540	81.80	2.8	.....	13.3	3.8	1.7	.6	.1	.0	6.2	7.1	Nov. 30, 1914	9.15	25.16	1.0283	9.0	.....	2.713
21	47	....	....	1.0223	6.143	16.0	June 18, 1915	9.15	32.5	128.5	1.0600	88.544	7.6	12.137	14.4	4.6	1.2	.6	.0	.....	6.4	8.0	June 22, 1915	9.15	27.84	1.0318	14.2	7.390	2.830
8	48	....	....	1.0222	5.958	15.0	Nov. 18, 1914	9.15	32.5	128.5	1.0448	69.776	2.2	.....	11.1	3.1	1.6	.1	.0	.0	4.8	6.3	Nov. 23, 1914	9.15	26.44	1.0246	8.0	.....	2.186
9	48	....	....	1.0234	5.843	16.4	Nov. 25, 1914	9.15	32.5	128.5	1.0544	88.47	3.4	.....	13.2	3.2	1.9	.5	.2	.0	5.8	7.4	Nov. 30, 1914	9.15	33.62	1.0298	8.8	.....	2.588
10	48	....	....	1.0243	6.170	18.6	Jan. 21, 1915	9.15	32.5	128.5	1.0488	79.16	4.4	9.638	12.1	3.3	1.1	.3	.2	.1	4.9	7.2	Jan. 26, 1915	9.15	32.40	1.0287	8.0	6.237	2.070
9	49	....	....	1.0234	5.843	16.4	Nov. 25, 1914	9.15	32.5	128.5	1.0417	57.728	3.3	.....	10.5	3.3	.5	.9	+.3	.0	4.4	6.1	Nov. 30, 1914	9.15	19.84	1.0251	8.8	.....	1.707
10	49	....	....	1.0243	6.170	18.6	Jan. 21, 1915	9.15	32.5	128.5	1.0384	52.40	5.6	7.329	9.9	2.4	1.4	.1	.0	.1	3.9	6.0	Jan. 26, 1915	9.15	16.48	1.0239	10.0	5.021	1.514
10	50	....	....	1.0243	6.170	18.6	Jan. 21, 1915	9.15	32.5	128.5	1.0495	94.92	3.2	10.301	12.1	3.1	.3	+.1	−.2	.0	3.5	8.6	.....do.....	9.15	56.28	1.0341	7.0	7.207	1.4707
11	50	....	22.0	1.0262	5.398	26.4	Feb. 11, 1915	9.15	32.5	128.5	1.0543	97.936	2.4	12.325	13.3	3.0	.5	.2	.2	.....	3.9	9.4	Feb. 16, 1915	9.15	61.74	41.0392	7.2	9.490	1.578
14	50	....	22.5	1.0235	5.784	24.5	Mar. 18, 1915	9.15	32.5	128.5	1.0440	83.38	2.8	9.190	11.0	2.9	.4	.3	+.2	.....	3.4	7.6	Mar. 23, 1915	9.15	51.26	41.0302	5.6	6.438	1.320
17	55	11.4	....	1.0216	5.922	18.7	Apr. 15, 1915	9.15	32.5	128.5	1.0470	64.48	3.2	9.426	11.8	3.6	1.5	.3	.0	.....	5.4	6.4	Apr. 20, 1915	9.15	14.74	1.0245	8.4	5.603	2.382
17	55	11.4	....	1.0216	5.922	18.7	.....do.....	9.15	32.5	128.5	1.0454	62.44	3.0	9.115	11.4	3.5	1.5	.2	.2	.....	5.4	6.0	.....do.....	9.15	13.76	1.0237	8.8	5.347	2.315
16	55	13.9	18.5	1.0223	6.167	26.2	Apr. 1, 1915	9.15	32.5	128.5	1.0498	58.12	2.6	9.266	12.2	3.5	1.5	.2	.1	.....	5.3	6.9	Apr. 6, 1915	9.15	16.04	1.0274	8.0	5.971	2.311
16	55	13.9	18.5	1.0223	6.167	26.2	.....do.....	9.15	32.5	128.5	1.0478	56.40	2.5	9.564	11.9	3.3	1.6	.2	.1	.....	5.2	6.7	.....do.....	9.15	10.28	1.0269	7.6	5.783	2.259
18	55	11.4	....	1.0210	6.009	22.3	May 6, 1915	9.15	32.5	128.5	1.0498	59.74	3.2	10.422	12.2	3.7	1.3	−.3	+.2	−.1	5.1	7.1	May 11, 1915	9.15	10.64	1.0275	7.6	6.289	2.224
16	56	13.9	18.5	1.0223	6.167	26.2	Apr. 1, 1915	9.15	32.5	128.5	1.0514	65.20	4.0	9.567	12.4	3.4	1.6	.5	.1	.1	5.6	6.8	Apr. 6, 1915	9.15	14.54	1.0270	8.6	5.842	2.390
16	56	13.9	18.5	1.0223	6.167	26.2	.....do.....	9.15	32.5	128.5	1.0509	64.60	4.0	8.858	12.4	3.1	1.7	.6	.2	.....	5.6	6.8	.....do.....	9.15	14.42	1.0268	8.6	5.848	2.395
17	56	11.4	....	1.0216	5.922	18.7	Apr. 15, 1915	9.15	32.5	128.5	1.0475	57.344	2.4	9.428	12.0	3.1	1.8	.2	.1	.....	5.2	6.8	Apr. 20, 1915	9.15	10.22	1.0268	7.6	5.873	2.259
17	56	11.4	....	1.0216	5.922	18.7	.....do.....	9.15	32.5	128.5	1.0498	60.10	2.6	9.979	12.4	3.4	1.7	.1	.0	.....	5.2	7.2	.....do.....	9.15	11.00	1.0278	7.4	6.160	2.345
18	56	11.4	....	1.0210	6.009	22.3	May 6, 1915	9.15	32.5	128.5	1.0487	66.52	4.4	11.110	12.3	3.7	1.5	.3	.0	.1	5.7	6.6	May 11, 1915	9.15	14.60	1.0262	11.2	6.070	2.543
20	56	13.1	....	1.0230	5.650	18.0	June 10, 1915	9.15	32.5	128.5	1.0429	56.904	4.5	8.606	10.7	3.6	1.1	.2	.0	.....	4.9	5.8	June 15, 1915	9.15	12.92	1.0227	9.6	5.278	1.968
20	56	13.1	....	1,0230	5.650	18.0	.....do.....	9.15	32.5	128.5	1.0542	71.288	4.8	10.750	13.1	3.4	1.8	.7	.1	.....	6.0	7.1	.....do.....	9.15	16.24	1.0287	12.0	6.493	2.590
17	57	11.4	....	1.0216	5.922	18.7	Apr. 15, 1915	9.15	32.5	128.5	1.0529	70.24	2.7	10.614	13.1	4.0	1.5	.3	.1	.....	5.9	7.2	Apr. 20, 1915	9.15	13.54	1.0279	7.4	6.264	2.558
17	57	11.4	....	1.0216	5.922	18.7	.....do.....	9.15	32.5	128.5	1.0509	66.32	2.4	10.076	12.5	3.5	1.7	.3	.2	.....	5.7	6.8	.....do.....	9.15	13.78	1.0263	7.4	6.023	2.543
18	57	11.4	....	1.0210	6.009	22.3	May 6, 1915	9.15	32.5	128.5	1.0463	62.02	2.8	9.962	11.5	3.9	1.2	.2	+.1	−.1	5.2	6.3	May 11, 1915	9.15	12.76	1.0247	7.6	5.781	2.318
18	57	11.4	....	1.0210	6.009	22.3	.....do.....	9.15	32.5	128.5	1.0400	52.26	2.4	8.705	10.0	3.7	.9	.2	+.1	.0	4.7	5.3	.....do.....	9.15	11.24	1.0213	6.0	4.948	1.099
19	57	12.9	....	1.0232	5.541	16.5	May 13, 1915	9.15	32.5	128.5	1.0474	60.984	3.0	8.539	11.7	3.6	1.3	.4	.1	.....	5.4	6.3	May 18, 1915	9.15	12.86	1.0240	8.8	5.805	2.266
19	57	12.9	....	1.0232	5.541	16.5	.....do.....	9.15	32.5	128.5	1.0472	60.476	3.0	8.465	11.5	3.3	1.5	.4	.0	.....	5.2	6.3	.....do.....	9.15	12.48	1.0246	8.8	5.951	2.274

TABLE 3.—*Fermentation record*—Continued.

Fermentation No.	Cook No.	Yeast. Seed yeast. Brix.	Yeast. Seed yeast. Acidity.	Yeast. 96-hour yeast. Sp. gr. at 15° C.	Yeast. 96-hour yeast. Alcohol (per cent by weight).	Yeast. 96-hour yeast. Acidity.	Fermenter set. Date.	Fermenter set. Hour.	Hours filling fermenter.	Hours fermenting, including time of filling.	Mash before fermentation. Sp. gr. at 15° C.	Mash before fermentation. Reducing sugars (grams per liter).	Mash before fermentation. Acidity.	Mash before fermentation. Total solids (per cent).	Mash before fermentation. Brix.	Brix record (decrease in Brix). First day.	Brix record (decrease in Brix). Second day.	Brix record (decrease in Brix). Third day.	Brix record (decrease in Brix). Fourth day.	Brix record (decrease in Brix). Fifth day.	Attenuation (degrees).	Beer. Brix fourth day.	Beer. Distillation. Date.	Beer. Distillation. Hour.	Beer. Reducing sugars (grams per liter).	Beer. Sp. gr. at 15° C.	Beer. Acidity.	Beer. Total solids (per cent by weight).	Beer. Alcohol (per cent by weight).
								a. m.																a. m.						
18	58	11.4	....	1.0210	6.009	22.3	May 6, 1915	9.15	32.5	128.5	1.0468	75.81	3.2	10.996	11.7	3.8	1.3	0.1	0.0	0.0	5.2	6.5	May 11, 1915	9.15	29.26	1.0258	7.2	6.204	2.218
18	58	11.4	....	1.0210	6.009	22.3	.....do.....	9.15	32.5	128.5	1.0497	81.48	2.6	11.006	12.4	3.9	1.4	.1	.0	.0	5.4	7.0	.....do.....	9.15	31.12	1.0275	6.3	6.484	2.117
19	58	12.9	....	1.0232	5.541	16.5	May 13, 1915	9.15	32.5	128.5	1.0523	83.152	3.0	9.679	12.7	3.5	1.4	.4	.1	.....	5.4	7.3	May 18, 1915	9.15	32.28	1.0285	7.8	7.196	2.421
19	58	12.9	....	1.0232	5.541	16.5	.....do.....	9.15	32.5	128.5	1.0540	87.192	3.0	10.598	13.3	3.5	1.5	.6	.1	.....	5.7	7.6	.....do.....	9.15	34.12	1.0300	9.2	7.453	2.500
20	58	13.1	....	1.0230	5.650	18.0	June 10, 1915	9.15	32.5	128.5	1.0553	87.792	2.5	11.180	13.2	3.2	1.8	.6	.1	.....	5.7	7.5	June 15, 1915	9.15	33.80	1.0300	10.0	7.063	2.456
18	59	11.4	....	1.0210	6.009	22.3	May 6, 1915	9.15	32.5	128.5	1.0502	57.96	3.4	8.716	10.0	3.2	1.3	.2	.0	.1	4.7	5.3	May 11, 1915	9.15	14.96	1.0206	6.2	4.832	1.843
19	59	12.9	....	1.0232	5.541	16.5	May 13, 1915	9.15	32.5	128.5	1.0440	63.48	2.8	8.381	10.8	3.4	1.3	.3	.0	.....	5.0	5.8	May 18, 1915	9.15	16.04	1.0223	7.2	5.725	2.147
19	59	12.9	....	1.0232	5.541	16.5	.....do.....	9.15	32.5	128.5	1.0477	67.40	2.7	8.812	11.5	3.5	1.5	.4	.1	.....	5.5	6.0	.....do.....	9.15	17.16	1.0245	7.2	5.802	2.382
20	59	13.1	....	1.0230	5.650	18.0	June 10, 1915	9.15	32.5	128.5	1.0552	80.512	4.0	11.220	13.3	3.2	2.1	.7	.2	.....	6.2	7.1	June 15, 1915	9.15	21.64	1.0282	11.2	6.558	2.694
19	60	12.9	....	1.0232	5.541	16.5	May 13, 1915	9.15	32.5	128.5	1.0464	68.048	4.2	8.778	11.2	3.6	1.2	.3	.0	.....	5.1	6.1	May 18, 1915	9.15	19.68	1.0241	9.2	5.849	2.246
19	60	12.9	....	1.0232	5.541	16.5	.....do.....	9.15	32.5	128.5	1.0439	64.72	4.2	8.152	10.8	3.3	1.4	.2	.0	.....	4.9	5.9	.....do.....	9.15	18.60	1.0230	8.0	5.690	2.072
20	60	13.1	....	1.0230	5.650	18.0	June 10, 1915	9.15	32.5	128.5	1.0532	77.34	4.1	10.750	12.9	3.4	1.8	.4	.1	.....	5.7	7.2	June 15, 1915	9.15	31.44	1.0286	13.3	6.713	2.469
20	60	13.1	....	1.0230	5.650	18.0	.....do.....	9.15	32.5	128.5	1.0500	72.16	4.0	10.650	12.2	3.1	1.8	.4	.1	.....	5.5	6.7	.....do.....	9.15	23.00	1.0265	12.0	6.264	2.474
21	60	....	....	1.0223	6.143	16.0	June 18, 1915	9.15	32.5	128.5	1.0513	77.48	4.4	11.035	12.6	4.5	1.0	.3	.0	.....	5.8	6.8	June 22, 1915	9.15	24.40	1.0269	11.2	6.439	2.517
20	61	13.1	....	1.0230	5.650	18.0	June 10, 1915	9.15	32.5	128.5	1.0480	70.432	2.2	9.440	11.7	3.6	1.5	.3	.2	.....	5.6	6.1	June 15, 1915	9.15	20.12	1.0246	7.8	5.810	2.381
20	61	13.1	....	1.0230	5.650	18.0	.....do.....	9.15	32.5	128.5	1.0470	86.464	1.8	8.233	11.5	3.5	1.8	.1	.1	.....	5.5	6.0	.....do.....	9.15	20.20	1.0241	7.8	5.702	2.229
21	61	....	....	1.0223	6.143	16.0	June 18, 1915	9.15	32.5	128.5	1.0512	75.00	3.2	10.691	12.3	4.7	.8	.2	.1	.....	5.8	6.5	June 22, 1915	9.15	20.70	1.0260	8.0	6.172	2.495
21	61	....	....	1.0223	6.143	16.0	.....do.....	9.15	32.5	128.5	1.0519	94.616	3.6	10.777	12.4	3.9	1.5	.4	+ .1	.....	5.7	6.7	.....do.....	9.15	21.52	1.0264	8.8	6.164	2.595
22	62	12.0	22.5	1.0253	5.93	27.2	Oct. 29, 1915	9.15	....	.....	1.0470	60.08	5.0	9.87	11.5	1.4	.5	.3	.0	.1	2.2	9.3	Nov. 2, 1915	9.15	36.00	1.0363	11.4	7.387	1.061
23	62	11.0	26.0	1.0259	5.907	25.2	Nov. 4, 1915	9.15	....	.....	1.0480	63.60	5.4	9.227	11.8	2.3	.4	.1	+ .1	.0	2.7	9.1	Nov. 9, 1915	9.15	36.76	1.0365	11.6	7.42	1.119
24	62	14.2	24.0	1.0310	6.052	32.8	Nov. 11, 1915	9.15	....	.....	1.0537	68.98	8.0	10.75	13.0	2.6	.1	.1	.2	.0	3.0	10.0	Nov. 16, 1915	9.15	41.56	1.0414	13.4	8.802	1.095
25	62	15.2	28.0	1.0346	6.089	34.0	Nov. 18, 1915	9.15	....	.....	1.0380	49.88	5.0	8.69	9.9	2.3	.2	.1	.0	.0	2.6	7.3	Nov. 23, 1915	9.15	27.98	1.0292	10.0	6.062	0.991
22	63	12.0	22.5	1.0253	5.93	27.2	Oct. 29, 1915	9.15	....	.....	1.0471	61.58	5.2	9.82	11.6	2.6	1.9	.6	.1	+ .1	5.2	6.4	Nov. 2, 1915	9.15	15.84	1.0256	11.2	5.869	2.184
23	63	11.0	26.0	1.0259	5.907	25.2	Nov. 4, 1915	9.15	....	.....	1.0531	70.38	4.4	10.481	12.9	3.9	1.6	.1	.1	.0	5.7	7.2	Nov. 9, 1915	9.15	17.98	1.0284	11.0	6.578	2.450
24	63	14.2	24.0	1.0310	6.052	32.8	Nov. 11, 1915	9.15	....	.....	1.0504	63.23	4.8	10.277	11.8	4.1	.9	.1	.0	.0	5.1	6.7	Nov. 16, 1915	9.15	16.22	1.0268	11.0	6.264	2.172
25	63	15.2	28.0	1.0346	6.089	34.0	Nov. 18, 1915	9.15	....	.....	1.0460	60.72	4.0	10.49	11.8	4.5	.5	.4	.0	.0	5.4	6.4	Nov. 23, 1915	9.15	1 5.48	1.0248	10.4	5.79	2.244
26	63	15.0	....	1.0366	6.029	39.2	Dec. 2, 1915	9.15	....	.....	1.0472	61.26	5.0	9.34	11.5	4.2	.9	.0	+ .1	.....	5.0	6.5	Dec. 7, 1915	9.15	1 3.72	1.0262	11.6	5.85	2.105
29	63	9.6	17.6	1.0204	5.155	20.0	Jan. 13, 1916	9.15	....	.....	1.0308	40.04	2.4	5.98	7.5	1.4	.1	.2	.0	.....	1.7	5.8	Jan. 18, 1916	9.15	2 2.42	1.0234	6.8	5.00	0.694
22	64	12.0	22.5	1.0253	5.93	27.2	Oct. 29, 1915	9.15	....	.....	1.0564	81.38	3.4	11.79	13.8	2.7	1.9	1.3	.6	.0	6.5	7.3	Nov. 2, 1915	9.15	2 1.22	1.0292	10.0	6.669	2.852
23	64	11.0	26.0	1.0259	5.907	25.2	Nov. 4, 1915	9.15	....	.....	1.0558	82.77	4.2	11.789	13.8	4.0	2.0	.6	.1	.0	6.7	7.1	Nov. 9, 1915	9.15	1 9.96	1.0282	11.5	6.972	2.908
24	64	14.2	24.0	1.0310	6.052	32.8	Nov. 11, 1915	9.15	....	.....	1.0473	66.88	3.8	9.675	11.6	4.0	1.3	.0	.2	.0	5.5	6.1	Nov. 16, 1915	9.15	1 6.32	1.0243	10.0	5.85	2.284

25	64	15.2	28.0	1.0346	6.089	34.0	Nov.	18, 1915	9.15	....	.....	1.0645	90.616	4.4	14.21	15.4	4.0	2.1	.8	.2	.1	7.1	8.3	Nov.	23, 1915	9.15	23.64	1.0334	10.8	7.85	83.222
22	65	12.0	22.5	1.0253	5.93	27.2	Oct.	29, 1915	9.15	....	.....	1.0549	84.92	2.8	11.18	13.4	3.5	1.5	1.0	.0	.0	6.0	7.4	Nov.	2, 1915	9.15	28.38	1.0291	8.0	6.50	82.585
23	65	11.0	26.0	1.0259	5.907	25.2	Nov.	4, 1915	9.15	....	.....	1.0498	77.92	2.8	10.66	12.3	4.3	1.2	.1	.0	.0	5.6	6.7	Nov.	9, 1915	9.15	25.98	1.0262	8.0	6.34	92.358
24	65	14.2	24.0	1.0310	6.052	32.8	Nov.	11, 1915	9.15	....	.....	1.0540	82.304	4.0	11.54	12.8	4.0	1.5	.1	.0	.1	5.6	7.2	Nov.	16, 1915	9.15	27.40	1.0287	9.6	6.57	92.382
25	65	15.2	28.0	1.0346	6.089	34.0	Nov.	18, 1915	9.15	....	.....	1.0595	90.736	4.2	12.38	14.7	4.7	1.8	.3	.0	.0	6.8	7.9	Nov.	23, 1915	9.15	30.94	1.0319	10.0	7.55	42.815
26	65	15.0	....	1.0366	6.029	39.2	Dec.	2, 1915	9.15	....	.....	1.0570	86.416	4.5	11.31	13.7	4.4	1.5	.3	.0	.....	6.2	7.5	Dec.	7, 1915	9.15	28.06	1.0315	5.6	5.65	2.709
27	65	13.5	32.0	1.0331	5.982	39.0	Dec.	16, 1915	9.15	....	.....	1.0519	77.98	4.0	10.79	12.6	4.6	1.0	.2	.0	.....	5.8	6.8	Dec.	21, 1915	9.15	24.80	1.0269	8.8	6.45	2.361
29	65	9.6	17.6	1.0204	5.155	20.0	Jan.	13, 1916	9.15	....	.....	1.0428	67.24	3.6	8.51	11.2	3.7	1.4	.1	.1	.....	4.3	5.9	Jan.	18, 1916	9.15	20.94	1.0239	8.0	5.50	2.197
22	66	12.0	22.5	1.0253	5.93	27.2	Oct.	29, 1915	9.15	....	.....	1.0524	76.49	2.8	15.85	13.0	3.9	2.2	.3	.1	.0	6.5	6.5	Nov.	2, 1915	9.15	21.00	1.0258	8.4	6.09	52.709
23	66	11.0	26.0	1.0259	5.907	25.2	Nov.	4, 1915	9.15	....	.....	1.0479	69.75	3.4	9.315	11.9	4.0	1.7	.2	.1	.0	6.0	5.9	Nov.	9, 1915	9.15	15.34	1.0233	8.1	5.58	72.482
24	66	14.2	24.0	1.0310	6.052	32.8	Nov.	11, 1915	9.15	....	.....	1.0518	74.76	4.0	10.526	12.6	4.3	1.6	.2	.0	.0	6.1	6.5	Nov.	16, 1915	9.15	16.28	1.0262	10.8	6.34	82.563
22	67	12.0	22.5	1.0253	5.93	27.2	Oct.	29, 1915	9.15	....	.....	1.0570	84.60	3.0	13.34	13.9	2.3	2.3	1.2	.7	.1	6.5	7.4	Nov.	2, 1915	9.15	25.16	1.0298	8.6	6.82	22.836
23	67	11.0	26.0	1.0259	5.907	25.2	Nov.	4, 1915	9.15	....	.....	1.0509	76.19	3.4	10.00	12.4	3.6	1.9	.4	.1	.0	6.0	6.4	Nov.	9, 1915	9.15	19.34	1.0252	8.8	5.99	2.599
24	67	14.2	24.0	1.0310	6.052	32.8	Nov.	11, 1915	9.15	....	.....	1.0527	78.184	3.0	10.584	12.6	3.0	1.7	.8	.3	.0	5.8	6.8	Nov.	16, 1915	9.15	18.92	1.0272	10.0	6.53	2.560
25	67	15.2	28.0	1.0346	6.089	34.0	Nov.	18, 1915	9.15	....	.....	1.0514	74.496	3.8	11.68	12.8	4.0	1.6	6	.1	+.1	6.3	6.5	Nov.	23, 1915	9.15	19.56	1.0254	9.6	5.76	62.589
26	67	15.0	....	1.0366	6.029	39.2	Dec.	2, 1915	9.15	....	.....	1.0518	92.928	4.4	10.49	12.5	4.0	1.6	.3	.1	.....	6.0	6.5	Dec.	7, 1915	9.15	19.16	1.0267	9.6	6.24	2.640
27	67	13.5	32.0	1.0331	5.982	39.0	Dec.	16, 1915	9.15	....	.....	1.0518	73.44	3.5	10.62	12.6	4.2	1.5	.4	.....	.....	6.1	6.5	Dec.	21, 1915	9.15	18.12	1.0257	8.0	6.30	2.681
28	67	13.3	20.0	1.0228	5.377	23.5	Jan.	6, 1915	9.15	....	.....	1.0504	71.84	3.7	10.89	12.3	4.2	1.5	.2	.1	.....	6.0	6.3	Jan.	11, 1916	9.15	18.62	1.0254	10.0	6.03	2.379
22	68	12.0	22.5	1.0253	5.93	27.2	Oct.	29, 1915	9.15	....	.....	1.0416	61.12	2.0	9.29	10.4	2.9	1.2	.6	.3	.0	5.1	5.3	Nov.	2, 1915	9.15	17.12	1.0206	7.2	4.96	32.126
23	68	11.0	26.0	1.0259	5.907	25.2	Nov.	4, 1915	9.15	....	.....	1.0461	68.98	2.8	9.003	11.4	3.4	1.7	.6	.1	.1	5.6	5.8	Nov.	9, 1915	9.15	17.56	1.0225	7.6	5.40	12.396
24	68	14.2	24.0	1.0310	6.052	32.8	Nov.	11, 1915	9.15	....	.....	1.0541	81.72	3.0	10.693	13.4	3.9	1.5	.7	2	.1	6.3	7.1	Nov.	16, 1915	9.15	23.06	1.0283	10.4	6.83	2.562
25	68	15.2	28.0	1.0346	6.089	34.0	Nov.	18, 1915	9.15	....	.....	1.0487	72.65	2.6	10.86	12.0	3.6	1.7	.4	.1	.0	5.8	6.2	Nov.	23, 1915	9.15	19.32	1.0244	8.0	6.12	32.528
26	68	15.0	....	1.0366	6.029	39.2	Dec.	2, 1915	9.15	....	.....	1.0467	68.75	3.4	9.46	11.4	3.6	1.5	.5	.0	.....	5.6	5.8	Dec.	7, 1915	9.15	17.98	1.0246	8.4	4.69	2.352
27	68	13.5	32.0	1.0331	5.982	39.0	Dec.	16, 1915	9.15	....	.....	1.0519	76.36	3.6	10.75	12.7	3.8	1.7	.5	.2	.0	6.2	6.5	Dec.	21, 1915	9.17	20.56	1.0257	7.2	6.43	2.691
28	68	13.3	20.0	1.0228	5.377	23.5	Jan.	6, 1915	9.15	....	.....	1.0294	41.384	2.0	6.26	7.1	1.2	1.4	.2	.1	.....	2.9	4.2	Jan.	11, 1916	9.15	13.88	1.0168	7.2	3.72	1.283
23	69	11.0	26.0	1.0259	5.907	25.2	Nov.	4, 1915	9.15	....	.....	1.0490	88.30	3.6	9.642	11.9	2.7	2.0	.5	.1	.1	5.2	6.7	Nov.	9, 1915	9.15	22.72	1.0267	8.6	5.99	72.162
24	69	14.2	24.0	1.0310	6.052	32.8	Nov.	11, 1915	9.15	....	.....	1.0590	109.27	5.2	11.263	14.3	3.7	1.7	.4	.3	.0	6.1	8.2	Nov.	16, 1915	9.15	34.80	1.0328	14.8	7.93	2.498
25	69	15.2	28.0	1.0346	6.089	34.0	Nov.	18, 1915	9.15	....	.....	1.0528	78.376	3.2	11.39	13.0	3.5	1.6	.5	.1	.0	5.7	7.3	Nov.	23, 1915	9.15	25.72	1.0290	9.2	6.81	82.507
26	69	15.0	....	1.0366	6.029	39.2	Dec.	2, 1915	9.15	....	.....	1.0580	83.856	4.8	12.00	14.1	4.0	1.7	.4	.2	.....	6.3	7.8	Dec.	7, 1915	9.15	26.80	1.0328	10.7	6.48	2.609
27	69	13.5	32.0	1.0331	5.982	39.0	Dec.	16, 1915	9.15	....	.....	1.0507	73.55	3.2	10.28	12.3	3.3	1.5	.4	.2	.0	5.4	6.9	Dec.	21, 1915	9.15	23.74	1.0273	8.4	6.67	2.219
28	69	13.3	20.0	1.0228	5.377	23.5	Jan.	6, 1916	9.15	....	.....	1.0442	62.58	4.0	8.65	10.9	3.5	1.1	.1	.1	.....	4.8	6.1	Jan.	11, 1916	9.15	19.86	1.0241	9.6	5.67	1.943
29	69	9.6	17.6	1.0204	5.155	20.0	Jan.	13, 1916	9.15	....	.....	1.0520	75.152	4.0	9.96	12.5	2.8	1.9	.6	.3	.....	5.6	6.9	Jan.	18, 1916	9.15	23.08	1.0282	9.2	6.55	2.373
25	70	15.2	28.0	1.0346	6.089	34.0	Nov.	18, 1915	9.15	....	.....	1.0395	78.04	2.8	8.99	10.2	4.0	.9	.1	0	+.1	5.0	5.2	Nov.	23, 1915	9.15	24.88	1.0202	9.0	4.96	22.014
26	70	15.0	....	1.0366	6.029	39.2	Dec.	2, 1915	9.15	....	.....	1.0572	83.784	4.4	11.87	13.9	4.1	1.5	.8	.1	.....	6.5	7.4	Dec.	7, 1915	9.15	28.48	1.0304	8.8	6.30	2.421
27	70	13.5	32.0	1.0331	5.982	39.0	Dec.	16, 1915	9.15	....	.....	1.0339	60.20	2.6	8.76	10.2	4.1	.8	.1	.....	.....	5.0	5.2	Dec.	21, 1915	9.15	19.00	1.0205	6.4	5.06	1.940
28	71	15.0	....	1.0366	6.029	39.2	Dec.	2, 1915	9.15	....	.....	1.0590	86.344	5.2	12.03	14.1	3.6	1.8	.9	.4	.....	6.7	7.4	Dec.	7, 1915	9.15	24.18	1.0308	10.0	7.33	2.949
27	71	13.5	32.0	1.0331	5.982	39.0	Dec.	16, 1915	9.15	....	.....	1.0510	75.416	2.8	10.90	12.2	3.8	1.5	.5	.1	.0	5.9	6.3	Dec.	21, 1915	9.15	19.92	1.0221	8.0	6.28	2.624
28	71	13.3	20.0	1.0228	5.377	23.5	Jan.	6, 1915	9.15	....	.....	1.0495	73.064	3.6	10.51	11.9	3.6	1.4	.7	.1	.....	5.8	6.1	Jan.	11, 1916	9.15	19.38	1.0247	10.0	5.85	2.366
29	71	9.6	17.6	1.0204	5.155	20.0	Jan.	13, 1916	9.15	....	.....	1.0408	60.70	3.8	8.03	12.4	5.1	1.6	.6	.1	.....	7.4	5.0	Jan.	18, 1916	9.15	14.42	1.0202	8.0	4.61	2.073
30	71	10.0	18.0	1.0201	5.264	20.5	Jan.	19, 1916	9.15	....	.....	1.0528	79.27	3.5	11.73	13.0	3.8	1.8	.7	2	.....	6.5	6.5	Jan.	24, 1916	9.15	20.88	1.0247	8.4	5.93	2.752
31	71	11.8	18.8	1.0212	5.204	20.8	Feb.	2, 1916	9.15	....	.....	1.0510	81.41	4.0	11.23	13.6	3.3	1.8	1.4	.....	.....	6.5	7.1	Feb.	9, 1916	9.15	23.00	1.0284	10.8	6.80	2.786
32	71	10.3	18.0	1.0206	5.168	19.2	Feb.	16, 1916	9.15	....	.....	1.0565	82.79	4.0	12.56	13.6	3.9	1.7	.9	.1	.....	6.6	7.0	Feb.	21, 1916	9.15	22.56	1.0280	10.4	6.86	2.709
26	72	15.0	....	1.0366	6.029	39.2	Dec.	2, 1915	9.15	32.5	138.5	1.0591	81.408	4.4	11.90	14.2	3.1	1.2	.5	.1	.....	4.9	9.3	Dec.	7, 1915	9.15	36.08	1.0388	9.6	8.99	2.007
27	72	13.5	32.0	1.0331	5.982	39.0	Dec.	16, 1915	9.15	32.5	138.5	1.0501	67.34	3.7	11.86	12.1	2.9	.7	.4	.0	.....	4.0	8.1	Dec.	21, 1915	9.15	30.32	1.0322	8.7	7.37	1.725
28	72	13.3	20.0	1.0228	5.377	23.5	Jan.	6, 1916	9.15	32.5	138.5	1.0494	67.38	4.0	10.48	11.9	3.1	.8	.....	.1	.....	4.0	7.9	Jan.	11, 1916	9.15	29.76	1.0325	8.6	7.56	1.584
30	72	10.0	18.0	1.0201	5.264	20.5	Jan.	19, 1916	9.15	32.5	138.5	1.0490	65.73	3.4	10.63	11.9	2.6	1.2	.1	.1	.....	4.0	7.9	Jan.	24, 1916	9.15	29.02	1.0314	8.2	6.45	1.753
31	72	11.8	18.8	1.0212	5.204	20.8	Feb.	2, 1916	9.15	32.5	138.5	1.0547	73.96	4.2	11.178	13.4	3.0	1.0	.2	.3	.....	4.5	8.9	Feb.	7, 1916	9.15	33.44	1.0359	10.4	8.33	1.911
33	72	15.3	22.0	1.0336	5.815	27.4	Mar.	30, 1916	9.15	32.5	138.5	1.0491	68.66	3.0	10.36	12.0	3.6	.4	.....	.....	.....	4.0	8.0	Mar.	6, 1916	9.15	30.42	1.0321	4.8	7.34	1.690
27	73	13.5	32.0	1.0331	5.982	39.0	Dec.	16, 1915	9.15	32.5	138.5	1.0528	75.904	4.8	10.42	12.6	2.1	.3	.1	.1	.....	2.6	10.0	Dec.	21, 1915	9.15	50.12	1.0401	10.4	8.91	1.086
28	73	13.3	20.0	1.0228	5.377	23.5	Jan.	6, 1916	9.15	32.5	138.5	1.0479	66.82	5.0	9.76	11.5	2.0	.2	.....	.1	.....	2.3	9.2	Jan.	11, 1916	9.15	43.10	1.0378	9.2	8.40	0.988
29	73	9.6	17.6	1.0204	5.155	20.0	Jan.	13, 1916	9.15	32.5	138.5	1.0485	68.608	5.4	9.35	11.8	2.1	.4	.1	.0	.....	2.6	9.2	Jan.	18, 1916	9.15	43.26	1.0380	8.8	8.27	1.118
30	73	10.0	18.0	1.0201	5.264	20.5	Jan.	19, 1916	9.15	32.5	138.5	1.0503	69.96	5.6	10.64	12.2	2.2	.4	.....	+.1	.....	2.5	9.7	Jan.	24, 1916	9.15	45.57	1.0385	10.0	7.64	1.103

TABLE 3.—*Fermentation record*—Continued.

Fermentation No.	Cook No.	Yeast. Seed yeast. Brix.	Yeast. Seed yeast. Acidity.	Yeast. 96-hour yeast. Sp. gr. at 15° C.	Yeast. 96-hour yeast. Alcohol (per cent by weight).	Yeast. 96-hour yeast. Acidity.	Fermenter set. Date.	Fermenter set. Hour.	Hours filling fermenter.	Hours fermenting, including time of filling.	Mash before fermentation. Sp. gr. at 15° C.	Mash before fermentation. Reducing sugars (grams per liter).	Mash before fermentation. Acidity.	Mash before fermentation. Total solids (per cent).	Mash before fermentation. Brix.	Brix record (decrease in Brix). First day.	Brix record (decrease in Brix). Second day.	Brix record (decrease in Brix). Third day.	Brix record (decrease in Brix). Fourth day.	Brix record (decrease in Brix). Fifth day.	Attenuation (degrees).	Beer. Brix fourth day.	Beer. Distillation. Date.	Beer. Distillation. Hour.	Beer. Reducing sugars (grams per liter).	Beer. Sp. gr. at 15° C.	Beer. Acidity.	Beer. Total solids (per cent by weight).	Beer. Alcohol (per cent by weight).
								a. m.																	a. m.					
31	73	11.8	18.8	1.0212	5.204	20.8	Feb. 2, 1916	9.15	32.5	138.5	1.0490	68.31	4.8	10.43	11.8	1.8	0.2	.....	0.3	.....	2.3	9.5	Feb. 7, 1916	9.15	45.32	1.0378	10.0	8.36	1.008
32	73	10.3	18.0	1.0206	5.168	19.2	Mar. 16, 1916	9.15	32.5	138.5	1.0438	60.78	4.6	9.01	10.9	2.1	.2	.....	.....	.....	2.3	8.6	Feb. 21, 1916	9.15	40.42	1.0342	10.0	7.54	0.952
28	74	13.3	20.0	1.0228	5.377	23.5	Jan. 6, 1916	9.15	32.5	138.5	1.0508	71.944	3.1	10.45	12.4	3.0	1.6	1.0	.4	0.1	6.0	6.4	Jan. 11, 1916	9.15	18.38	1.0254	10.0	6.41	2.521
29	74	9.6	17.6	1.0204	5.155	20.0	Jan. 13, 1916	9.15	32.5	138.5	1.0531	75.952	4.0	10.03	12.9	2.7	2.0	1.2	.5	.0	6.4	6.5	Jan. 18, 1916	9.15	18.72	1.0266	10.2	6.23	2.698
30	74	10.0	18.0	1.0201	5.264	20.5	Jan. 19, 1916	9.15	32.5	138.5	1.0510	72.72	3.8	10.86	12.3	3.4	1.9	.7	.1	.....	6.1	6.2	Jan. 24, 1916	9.15	18.00	1.0252	9.6	5.69	2.634
31	74	11.8	18.8	1.0212	5.204	20.8	Feb. 2, 1916	9.15	32.5	138.5	1.0520	71.90	4.2	11.00	12.6	3.1	1.4	.8	.6	.....	5.9	6.7	Feb. 7, 1916	9.15	19.76	1.0268	9.6	6.52	2.568
32	74	10.3	18.0	1.0206	5.168	19.2	Feb. 16, 1916	9.15	32.5	138.5	1.0523	74.45	3.6	12.17	12.6	3.4	1.5	.9	.3	.....	6.1	6.5	Feb. 21, 1916	9.15	18.64	1.0257	10.5	6.30	2.574
33	74	15.3	22.0	1.0336	5.815	27.4	Feb. 30, 1916	9.15	32.5	138.5	1.0490	69.43	4.2	.....	12.1	4.3	1.5	.2	.....	.....	6.0	6.1	Mar. 6, 1916	9.15	15.52	1.0240	5.2	5.84	2.603
34	74	11.3	21.3	1.0336	5.771	24.6	Mar. 8, 1916	9.15	32.5	138.5	1.0510	73.06	4.7	11.31	12.4	3.9	1.5	.6	.2	.....	6.2	6.2	Mar. 13, 1916	9.15	16.42	1.0248	8.4	5.94	2.591
28	75	13.3	20.0	1.0228	5.377	23.5	Jan. 6, 1916	9.15	32.5	138.5	1.0540	73.936	4.8	10.91	12.9	2.8	.7	.0	.1	.....	3.6	9.3	Jan. 11, 1916	9.15	37.88	1.0380	12.0	8.18	1.474
29	75	9.6	17.6	1.0204	5.155	20.0	Jan. 13, 1916	9.15	32.5	138.5	1.0513	71.384	5.2	9.64	12.4	2.5	.5	.2	.1	.....	3.3	9.1	Jan. 18, 1916	9.15	39.38	1.0377	9.6	8.50	1.450
30	75	10.0	18.0	1.0201	5.264	20.5	Jan. 19, 1916	9.15	32.5	138.5	1.0509	70.04	5.8	10.78	12.6	3.0	.5	.1	.1	.....	3.7	8.9	Jan. 24, 1916	9.15	34.14	1.0362	12.8	7.25	1.534
31	75	11.8	18.8	1.0212	5.204	20.8	Feb. 2, 1916	9.15	32.5	138.5	1.0498	66.77	8.6	10.42	12.2	2.7	.2	.2	.3	.....	3.4	8.8	Feb. 7, 1916	9.15	35.42	1.0358	12.0	7.79	1.448
32	75	10.3	18.0	1.0206	5.168	19.2	Feb. 16, 1916	9.15	32.5	138.5	1.0524	70.76	6.0	11.63	12.7	2.9	.5	.....	.1	.....	3.5	9.2	Feb. 21, 1916	9.15	46.06	1.0372	10.4	8.19	1.423
33	75	15.3	22.0	1.0336	5.815	27.4	Mar. 30, 1916	9.15	32.5	138.5	1.0372	48.80	4.6	7.66	9.2	2.3	.3	+.2	.1	.....	2.5	6.7	Mar. 6, 1916	9.15	25.48	1.0265	4.4	5.75	1.140
29	76	9.6	17.6	1.0204	5.155	20.0	Jan. 13, 1916	9.15	32.5	138.5	1.0451	63.16	4.0	8.46	11.1	1.1	.3	.1	.1	.....	1.6	9.5	Jan. 18, 1916	9.15	48.28	1.0387	8.0	7.91	.582
30	76	10.0	18.0	1.0201	5.264	20.5	Jan. 19, 1916	9.15	32.5	138.5	1.0503	71.76	5.2	10.77	12.3	1.1	.3	.1	.....	.....	1.5	10.8	Jan. 24, 1916	9.15	52.72	1.0442	9.2	8.47	.709
31	76	11.8	18.8	1.0212	5.204	20.8	Feb. 2, 1916	9.15	32.5	138.5	1.0486	64.24	6.0	9.382	11.5	.8	.1	.2	.2	.....	1.3	10.2	Feb. 7, 1916	9.15	51.38	1.0415	12.0	8.97	.576
32	76	10.3	18.0	1.0206	5.168	19.2	Feb. 16, 1916	9.15	32.5	138.5	1.0483	67.80	6.0	10.53	11.9	1.3	.1	.....	.2	.....	1.6	10.3	Feb. 21, 1916	9.15	53.78	1.0423	8.9	9.41	.528
31	77	11.8	18.8	1.0212	5.204	20.8	Feb. 2, 1916	9.15	32.5	138.5	1.0524	70.78	8.6	10.645	12.3	2.7	.6	.2	.1	.....	3.6	8.7	Feb. 7, 1916	9.15	35.88	1.0350	9.2	7.86	1.575
32	77	10.3	18.0	1.0206	5.168	19.2	Feb. 16, 1916	9.15	32.5	138.5	1.0509	71.57	5.3	11.06	12.4	3.2	.4	.0	.1	.....	3.7	8.7	Feb. 21, 1916	9.15	35.62	1.0351	8.6	7.96	1.623
33	77	16.0	22.0	1.0336	5.815	27.4	Mar. 1, 1916	9.15	32.5	138.5	1.0568	79.34	4.2	11.84	13.7	3.7	.2	.2	.1	.....	4.2	9.5	Mar. 6, 1916	9.15	38.70	1.0385	4.2	8.82	1.743
34	77	11.3	21.3	1.0336	5.771	24.6	Mar. 8, 1916	9.15	32.5	138.5	1.0518	71.58	4.5	10.89	12.6	3.5	.2	.2	.1	.....	4.0	8.6	Mar. 13, 1916	9.15	34.24	1.0351	8.0	7.78	1.565
32	78	10.3	18.0	1.0206	5.168	19.2	Feb. 16, 1916	9.15	32.5	138.5	1.0489	72.13	3.6	10.78	11.9	1.7	.3	.1	.....	.....	2.1	9.8	Feb. 21, 1916	9.15	49.48	1.0396	8.0	9.04	.971
33	78	16.0	22.0	1.0336	5.815	27.4	Mar. 1, 1916	9.15	32.5	138.5	1.0529	77.02	4.4	11.26	12.8	1.8	.4	.1	.....	.....	2.3	10.5	Mar. 6, 1916	9.15	54.09	1.0425	4.6	9.24	.988
34	78	11.3	21.3	1.0336	5.771	24.6	Mar. 8, 1916	9.15	32.5	138.5	1.0483	69.22	6.0	10.41	11.8	1.9	.1	.1	.1	.....	2.2	9.6	Mar. 13, 1916	9.15	47.10	1.0390	8.3	8.69	1.059
32	79	10.3	18.0	1.0206	5.168	19.2	Feb. 16, 1916	9.15	32.5	138.5	1.0486	64.20	6.0	10.97	11.9	1.9	.....	.5	.1	.....	2.5	9.4	Feb. 21, 1916	9.15	39.80	1.0375	10.0	8.30	.973
33	79	16.0	22.0	1.0336	5.815	27.4	Mar. 1, 1916	9.15	32.5	138.5	1.0480	61.98	3.2	9.99	11.7	2.1	.2	.1	.....	.....	2.4	9.3	Mar. 6, 1916	9.15	38.40	1.0376	5.2	8.27	1.070
34	79	11.3	21.3	1.0336	5.771	24.6	Mar. 8, 1916	9.15	32.5	138.5	1.0498	63.62	7.0	6.94	12.1	2.1	.2	.1	.1	.....	2.5	9.6	Mar. 13, 1916	9.15	39.12	1.0392	10.8	8.21	1.039
35	79	11.4	....	1.0237	5.939	18.0	Mar. 15, 1916	9.15	32.5	138.5	1.0517	68.66	7.8	10.15	12.6	2.4	.3	.....	.1	.....	2.8	9.8	Mar. 20, 1916	9.15	39.89	1.0409	10.8	8.56	1.148
36	79	12.2	18.8	1.236	5.549	20.4	Apr. 9, 1916	9.15	32.5	138.5	1.0321	39.78	4.4	6.57	7.9	1.4	.2	.....	.....	.....	1.6	6.3	.....	.....	23.56	1.0248	8.0	5.04	.727

33	80	16.0	22.0	1.0336	5.815	27.4	Mar. 1, 1916	9.15	32.5	138.5	1.0487	73.18	6.8	10.03	11.8	2.5	.3	.....	.1	.....	2.9	8.9	Mar. 6, 1916	9.15	43.76	1.0362	6.7	7.80	1.293
34	80	11.3	21.3	1.0336	5.771	24.6	Mar. 8, 1916	9.15	32.5	138.5	1.0534	76.14	7.6	11.02	13.0	2.8	.3	.....	.1	.....	3.2	10.8	Mar. 13, 1916	9.15	53.80	1.0432	11.0	9.35	.872
35	80	11.4	....	1.0237	5.939	18.0	Mar. 15, 1916	9.15	32.5	138.5	1.0529	74.02	8.4	10.39	12.8	1.5	.3	.1	.....	.....	1.9	10.9	Mar. 20, 1916	9.15	54.21	1.0450	12.0	9.32	.919
36	80	12.2	18.8	1.0236	5.549	20.4	Mar. 19, 1916	9.15	32.5	138.5	1.0541	74.736	8.6	11.00	13.3	1.2	.....	.7	.1	.....	2.0	11.3	Mar. 14, 1916	9.15	56.49	1.0465	16.0	9.29	.616
33	81	16.0	22.0	1.0336	5.815	27.4	Mar. 1, 1916	9.15	32.5	138.5	1.0498	74.47	8.0	10.22	12.3	2.7	.3	.1	.....	.....	3.1	9.2	Mar. 6, 1916	9.15	45.32	1.0373	6.8	8.20	1.190
34	81	11.3	21.3	1.0336	5.771	24.6	Mar. 8, 1916	9.15	32.5	138.5	1.0493	74.30	8.0	10.58	12.1	2.7	.3	.1	+.1	.....	3.0	9.1	Mar. 13, 1916	9.15	44.64	1.0363	12.8	7.97	1.336
35	81	11.4	....	1.0237	5.939	18.0	Mar. 15, 1916	9.15	32.5	138.5	1.0520	76.02	10.0	10.34	12.7	2.9	.2	.2	.1	.....	3.2	9.5	Mar. 20, 1916	9.15	45.84	1.0395	13.2	8.49	1.390
36	81	12.2	18.8	1.0236	5.549	20.4	Apr. 9, 1916	9.15	32.5	138.5	1.0412	59.52	8.2	11.18	10.2	2.2	.2	.2	.....	.....	2.6	7.6	Apr. 14, 1916	9.15	36.12	1.0308	10.0	6.26	.956
36	82	12.2	18.8	1.0236	5.549	20.4	Apr. 9, 1916	9.15	32.5	128.5	1.0429	61.66	9.2	8.95	10.6	1.8	.3	.1	.....	.....	2.2	8.4	Apr. 4, 1916	9.15	42.92	1.0338	13.2	6.97	.899
37	82	11.7	....	1.0235	5.915	22.0	Apr. 25, 1916	9.15	32.5	128.5	1.0510	79.66	11.2	9.52	12.8	1.4	.7	.3	.1	.....	2.5	10.3	Apr. 30, 1916	9.15	56.36	1.0424	12.0	8.90	.955
38	82	11.7	16.8	1.0247	6.065	21.0	May 3, 1916	9.15	32.5	128.5	1.0503	76.85	10.0	10.31	12.4	1.7	.....	.6	.1	.....	2.4	10.0	May 8, 1916	9.15	42.39	1.0417	16.0	8.38	.888
39	82	10.5	20.6	1.0224	5.210	28.8	May 10, 1916	9.15	32.5	128.5	1.0415	63.21	8.9	8.65	10.4	1.7	.2	.....	1	.....	2.0	8.4	May 15, 1916	9.15	43.10	1.0332	12.0	6.90	.784
40	82	....	16.7	1.0269	5.848	19.2	May 24, 1916	9.15	32.5	128.5	1.0446	67.22	9.8	8.59	....	.....	.....	.....	.....	.....	.....	.....	May 29, 1916	9.15	46.56	1.0367	12.5	7.38	.829
44	83	7.5	21.2	1.0203	6.011	20.2	Aug. 2, 1916	9.15	32.5	128.5	1.0500	54.80	8.4	10.32	....	.....	.....	.....	.....	.....	.....	.....	Aug. 7, 1916	9.15	20.24	1.0333	11.2	6.61	Lost.
43	83	11.6	22.0	1.0207	6.329	22.0	July 19, 1916	9.15	32.5	128.5	1.0469	52.80	8.4	9.84	....	.....	.....	.....	.....	.....	.....	.....	July 4, 1916	9.15	23.32	1.0330	11.0	7.50	1.413
36	83	12.2	18.8	1.0236	5.549	20.4	Apr. 9, 1916	9.15	32.5	128.5	1.0539	61.98	8.8	11.01	13.2	3.0	.9	.2	.....	.....	4.1	9.1	Apr. 14, 1916	9.15	24.70	1.0369	14.4	7.59	1.664
37	83	11.7	....	1.0235	5.915	22.0	Apr. 25, 1916	9.15	32.5	128.5	1.0592	68.23	10.0	10.50	14.5	2.4	1.5	.3	.2	.....	4.4	10.1	Apr. 30, 1916	9.15	27.20	1.0413	10.8	8.80	1.714
38	83	11.7	16.8	1.0247	6.065	21.0	May 3, 1916	9.15	32.5	128.5	1.0528	60.06	8.0	10.19	12.9	2.5	.....	1.3	.1	.....	3.9	9.0	May 8, 1916	9.15	24.46	1.0367	14.2	7.71	1.664
39	83	10.5	20.6	1.0224	5.210	28.8	May 10, 1916	9.15	32.5	128.5	1.0475	57.26	9.0	10.01	12.1	2.6	.7	.3	.1	.....	3.7	8.4	May 15, 1916	9.15	22.54	1.0336	12.8	7.02	1.514
40	83	....	16.7	1.0267	5.818	19.2	May 24, 1916	9.15	32.5	128.5	1.0540	62.65	8.4	10.08	....	.....	.....	.....	.....	.....	.....	.....	May 29, 1916	9.15	26.22	1.0385	12.0	7.90	51.743
4f	83	13.5	16.8	1.0210	5.915	22.0	June 7, 1916	9.15	32.5	128.5	1.0516	57.48	7.2	10.63	....	.....	.....	.....	.....	.....	.....	.....	June 12, 1916	9.15	33.32	1.0849	13.6	7.03	1.497
42	83	6.1	19.8	1.0187	6.170	19.2	July 12, 1916	9.15	32.5	128.5	1.0524	81.78	8.8	9.19	....	.....	.....	.....	.....	.....	.....	.....	July 17, 1916	9.15	22.84	1.0308	10.2	7.46	2.415
36	84	12.2	18.8	1.0236	5.549	20.4	Apr. 9, 1916	9.15	32.5	128.5	1.0496	59.64	3.4	8.59	9.7	2.8	1.5	.1	.2	.....	4.6	5.1	Apr. 14, 1916	9.15	17.96	1.0205	8.0	4.66	51.886
37	84	11.7	....	1.0235	5.915	22.0	Apr. 25, 1916	9.15	32.5	128.5	1.0524	83.57	5.0	9.67	13.1	2.6	2.4	.9	.2	.....	6.1	7.0	Apr. 30, 1916	9.15	22.34	1.0282	5.4	6.75	2,597
38	84	11.7	16.8	1.0247	6.065	21.0	May 3, 1916	9.15	32.5	128.5	1.0486	75.56	4.0	10.14	12.0	3.3	.....	2.2	.1	.....	5.6	6.4	May 8, 1916	9.15	23.04	1.0258	10.0	5.97	2.333
39	84	10.5	20.6	1.0224	5.210	28.8	May 10, 1916	9.15	22.5	128.5	1.0518	79.58	5.6	10.92	12.7	3.3	1.7	.8	.1	.....	5.9	6.8	May 15, 1916	9.15	24.98	1.0262	10.8	6.37	2.553
41	84	13.5	16.8	1.0210	5.915	22.0	June 7, 1916	9.15	22.5	128.5	1.0305	46.20	2.4	14.35	....	.....	.....	.....	.....	.....	.....	.....	June 7, 1916	9.15	11.96	1.0110	8.4	3.57	1.642
37	85	11.7	....	1.0235	5.915	22.0	Apr. 25, 1916	9.15	32.5	128.5	1.0329	60.64	3.0	6.40	8.8	3.5	.5	.1	.1	.....	4.2	4.6	Apr. 30, 1916	9.15	21.86	1.0179	3.8	4.33	1.704
38	85	11.7	16.8	1.0247	6.055	21.0	May 8, 1916	9.15	32.5	128.5	1.0526	91.10	4.2	11.44	12.8	3.9	.....	1.8	.1	.....	5.8	7.0	May 8, 1916	9.15	21.00	1.0282	10.0	6.56	2.310
39	85	10.5	20.6	1.0224	5.210	28.8	May 10, 1916	9.15	32.5	128.5	1.0519	89.16	5.2	11.28	12.8	4.0	1.5	.3	.0	.....	5.8	7.0	May 15, 1916	9.15	35.90	1.0274	8.0	6.58	2.385
40	85	....	16.7	1.0267	5.848	19.2	May 24, 1916	9.15	32.5	128.5	1.0533	93.02	5.2	10.38	....	.....	.....	.....	.....	.....	.....	.....	May 29, 1916	9.15	36.74	1.0285	8.6	6.63	2.591
41	85	13.5	16.8	1.0210	5.915	22.0	June 7, 1916	9.15	32.5	128.5	1.0569	77.76	5.0	12.62	....	.....	.....	.....	.....	.....	.....	.....	June 7, 1916	9.15	39.36	1.0202	9.8	7.14	2.842
38	86	11.7	16.8	1.0247	6.065	21.0	May 3, 1916	9.15	32.5	128.5	1.0438	65.94	4.0	9.30	10.9	3.2	.....	2.2	.1	.....	5.5	5.4	May 8, 1916	9.15	14.54	1.0218	8.2	5.05	52.175
39	86	10.5	20.6	1.0224	5.210	28.8	May 10, 1916	9.15	32.5	128.5	1.0520	77.72	4.4	10.87	512.8	3.5	2.0	.8	.1	.....	6.4	6.4	May 15, 1916	9.15	16.84	1.0235	9.2	6.03	2.716
40	86	....	16.7	1.0267	5.848	19.2	May 24, 1916	9.15	32.5	128.5	1.0478	70.99	4.0	8.88	11.8	3.4	2.2	.3	.1	.....	6.0	5.8	May 29, 1916	9.15	15.46	1.0232	8.4	5.38	2.502
41	86	13.5	16.8	1.0210	5.915	22.0	June 7, 1916	9.15	32.5	128.5	1.0544	104.80	6.2	11.45	14.2	3.7	1.5	1.2	.5	.....	7.9	6.3	June 7, 1916	9.15	17.56	1.0266	8.2	6.09	2.785
38	87	11.7	16.8	1.0247	6.065	21.0	May 3, 1916	9.15	32.5	128.5	1.0504	75.78	6.8	10.52	11.9	4.3	.....	1.0	.2	.....	5.5	6.4	May 8, 1916	9.15	20.56	1.0260	12.0	5.95	2.532
39	87	10.5	20.6	1.0224	5.210	28.8	May 10, 1916	9.15	32.5	128.5	1.0524	77.75	7.0	10.71	12.8	3.9	1.6	.5	.1	.....	6.1	6.7	May 15, 1916	9.15	21.64	1.0267	12.0	6.35	2.615
40	87	....	16.7	1.0267	5.848	19.2	May 24, 1916	9.15	32.5	128.5	1.0437	60.98	5.8	8.29	10.9	2.3	1.7	.5	.0	.....	4.5	6.4	May 29, 1916	9.15	19.92	1.0259	10.2	5.80	2.407
41	87	13.5	16.8	1.0210	5.915	22.0	June 7, 1916	9.15	32.5	128.5	1.0541	81.20	8.0	17.34	14.3	2.7	2.3	1.8	.2	.....	7.0	7.3	June 7, 1916	9.15	23.62	1.0270	10.0	6.71	2.493
42	87	6.1	19.8	1.0187	6.170	19.2	July 12, 1916	9.15	32.5	128.5	1.0494	60.72	7.6	8.74	11.9	2.4	1.6	1.5	+.1	.....	5.4	6.5	July 17, 1916	9.15	19.68	1.0238	8.2	5.59	1.650
39	88	10.5	20.6	1.0224	5.210	28.8	May 10, 1916	9.15	32.5	128.5	1.0525	85.76	7.0	11.20	12.9	2.0	.6	.3	.1	.....	3.0	9.9	May 5, 1916	9.15	54.23	1.0400	8.9	8.70	1.231
40	88	....	16.7	1.0267	5.848	19.2	May 24, 1916	9.15	32.5	128.5	1.0443	68.44	5.4	18.59	10.9	2.0	.2	.1	.1	.....	2.4	8.5	May 29, 1916	9.15	48.89	1.0348	8.0	7.31	1.1067
40	89	....	16.7	1.0267	5.848	19.2	May 24, 1916	9.15	32.5	128.5	1.0527	39.72	12.1	10.05	12.6	+.1	.0	.0	.3	.....	.3	12.3	May 29, 1916	9.15	37.66	1.0518	14.0	10.06	.171
41	89	13.5	16.8	1.0210	5.915	22.0	June 7, 1916	9.15	32.5	128.5	1.0900	69.68	24.6	8.02	20.9	.1	.2	+.1	.5	.....	.6	20.3	June 7, 1916	9.15	69.02	1.0900	25.6	17.00	.128
42	89	6.1	19.8	1.0187	6.170	19.2	July 12, 1916	9.15	32.5	128.5	1.0836	67.68	25.6	16.31	20.5	.5	.1	.2	.0	.....	.6	19.9	July 17, 1916	9.15	70.80	1.0763	22.4	16.10	.056
40	90	....	16.7	1.0267	5.848	19.2	May 24, 1916	9.15	32.5	128.5	1.0520	52.78	10.8	9.49	12.6	.2	.0	.....	.1	.....	.4	12.2	May 29, 1916	9.15	51.16	1.0502	12.0	9.77	.0802
41	90	13.5	16.8	1.0210	5.915	22.0	June 7, 1916	9.15	32.5	128.5	1.0819	94.48	20.4	17.76	20.4	.1	.0	.0	.0	.....	.1	20.3	June 12, 1916	9.15	92.88	1.0830	11.6	17.29	....
42	90	6.1	19.8	1.0187	6.170	19.2	July 12, 1916	9.15	32.5	128.5	1.0870	90.76	20.6	15.21	20.8	.5	+.1	.0	.0	.0	.0	20.8	July 17, 1916	9.15	93.48	1.0833	18.6	15.56	.147
43	90	11.6	22.0	1.0207	6.329	22.0	July 19, 1916	9.15	32.5	128.5	1.0875	95.36	18.8	17.66	20.6	.0	.2	.0	+.1	.....	....	20.7	July 24, 1916	9.15	97.60	1.0865	21.6	18.78	.152
41	91	13.5	16.8	1.0210	5.915	22.0	June 7, 1916	9.15	32.5	128.5	1.0865	112.92	12.4	18.82	20.3	.3	.....	.0	.0	.....	.3	20.0	June 12, 1916	9.15	113.84	1.0850	20.0	19.12	.074
43	91	11.6	22.0	1.0207	6.329	22.0	July 19, 1916	9.15	32.5	128.5	1.0488	64.04	4.8	11.04	12.0	.5	.3	.1	.3	.....	1.2	10.8	July 24, 1916	9.15	63.88	1.0444	8.0	10.16	.063

TABLE 3.—*Fermentation record*—Continued.

Fermentation No.	Cook No.	Yeast. Seed yeast. Brix.	Yeast. Seed yeast. Acidity.	Yeast. 96-hour yeast. Sp. gr. at 15° C.	Yeast. 96-hour yeast. Alcohol (per cent by weight).	Yeast. 96-hour yeast. Acidity.	Fermenter set. Date.	Fermenter set. Hour.	Hours filling fermenter.	Hours fermenting, including time of filling.	Mash before fermentation. Sp. gr. at 15° C.	Mash before fermentation. Reducing sugars (grams per liter).	Mash before fermentation. Acidity.	Mash before fermentation. Total solids (per cent).	Mash before fermentation. Brix.	Brix record (decrease in Brix). First day.	Brix record. Second day.	Brix record. Third day.	Brix record. Fourth day.	Brix record. Fifth day.	Attenuation (degrees).	Beer. Brix fourth day.	Beer. Distillation. Date.	Beer. Distillation. Hour.	Beer. Reducing sugars (grams per liter).	Beer. Sp. gr. at 15° C.	Beer. Acidity.	Beer. Total solids (per cent by weight).	Beer. Alcohol (per cent by weight).
								a. m.																*a. m.*					
42	92	6.1	19.8	1.0187	6.170	19.2	July 12, 1916	9.15	32.5	128.5	1.0540	79.52	12.8	10.03	13.0	0.5	+0.2	0.0	0.0	0.0	0.3	12.7	July 17, 1916	9.15	76.04	1.0505	10.8	9.46	0.790
43	92	11.6	22.0	1.0207	6.329	22.0	July 19, 1916	9.15	32.5	128.5	1.0528	80.80	10.2	11.55	13.0	.5	.0	.0	.0	.....	.4	12.6	July 24, 1916	9.15	76.44	1.0508	13.4	11.45	.324
44	92	7.5	21.2	1.0203	6.011	20.2	Aug. 2, 1916	9.15	32.5	128.5	1.0496	73.64	10.0	10.72	12.3	.8	.0	.1	.0	.....	.7	11.6	Aug. 7, 1916	9.15	66.44	1.0470	12.2	9.46	.223
45	92	8.7	20.0	1.0209	5.965	21.2	Aug. 23, 1916	9.15	32.5	128.5	1.0498	72.92	14.4	10.11	12.3	.8	.....	.0	.2	.....	1.0	11.3	Aug. 28, 1916	9.15	64.48	1.0456	12.8	9.70	.282
46	92	....	14.0	1.0186	5.772	16.0	Sept. 20, 1916	9.15	32.5	128.5	1.0477	71.84	10.4	10.02	12.6	5.9	.0	.0	.1	.....	6.0	6.6	Sept. 25, 1916	9.15	47.60	1.0273	13.2	10.11	2.24
42	93	6.1	19.8	1.0187	6.170	19.2	July 12, 1916	9.15	32.5	128.5	1.0846	92.68	25.0	16.64	20.0	.2	+.1	.0	.0	20.1	.0	20.0	July 17, 1912	9.15	85.36	1.0832	21.6	14.55	.....
44	93	7.5	21.2	1.0203	6.011	20.2	Aug. 2, 1916	9.15	32.5	128.5	1.0720	76.80	18.0	14.06	17.4	.1	.0	.1	.0	.....	.1	17.3	Aug. 7, 1916	9.15	76.72	1.0699	22.4	13.71	.0571
45	93	8.7	20.0	1.0209	5.965	21.2	Aug. 23, 1916	9.15	32.5	128.5	1.0856	91.12	26.8	16.79	20.7	.3	.2	+.3	.2	.....	.4	20.3	Aug. 28, 1916	9.15	90.68	1.0858	26.4	17.04	.0552
46	93	....	14.0	1.0186	5.772	16.0	Sept. 28, 1916	9.15	32.5	128.5	1.0480	67.84	13.6	9.444	11.8	.0	.0	.0	.0	.....	.0	11.8	Sept. 25, 1916	9.15	60.12	1.0478	14.2	9.217	.137
55	93	....	21.6	1.0200	6.141	17.3	Jan. 30, 1916	9.15	32.5	128.5	1.0489	51.92	17.6	9.674	12.0	.1	+1.0	.0	.1	.1	.1	11.9	Feb. 5, 1917	9.15	50.76	1.0480	16.6	10.060	.024
42	94	6.1	19.8	1.0187	6.170	19.2	July 12, 1916	9.15	32.5	128.5	1.0208	67.60	6.0	10.77	12.0	.8	.0	.0	11.0	.2	1.0	11.0	July 17, 1916	9.15	51.52	1.0360	11.2	8.37	.522
43	94	11.6	22.0	1.0207	6.329	22.0	July 19, 1916	9.15	32.5	128.5	1.0488	48.52	8.4	10.31	11.9	.7	.1	.2	.0	.....	1.1	10.8	July 29, 1916	9.15	51.20	1.0429	8.4	9.45	.584
44	94	7.5	21.2	1.0203	6.011	20.2	Aug. 2, 1916	9.15	32.5	128.5	1.0497	66.68	5.2	10.48	12.1	.8	.0	.0	.1	.....	.9	11.2	Aug. 7, 1916	9.15	56.56	1.0453	10.6	9.31	.331
45	94	8.7	20.0	1.0209	5.965	21.2	Aug. 23, 1916	9.15	32.5	128.5	1.0470	64.84	7.6	9.33	12.6	1.5	.2	.0	+.2	.....	1.3	11.3	Aug. 28, 1916	9.15	58.00	1.0459	12.0	9.02	.449
46	94	....	14.0	1.0186	5.772	16.0	Sept. 20, 1916	9.15	32.5	128.5	1.0517	69.36	6.6	8.894	12.4	.4	.0	.0	.0	.....	.4	12.0	Sept. 25, 1916	9.15	63.96	1.0497	7.6	10.01	.354
55	95	....	21.6	1.0200	6.141	17.3	Jan. 30, 1916	9.15	32.5	128.5	1.0689	90.84	8.0	14.000	16.4	.5	.0	.3	.0	.4	.4	16.0	Feb. 5, 1917	9.15	86.24	1.0674	13.0	14.560	.160
42	95	6.1	19.8	1.0187	6.170	19.2	July 12, 1916	9.15	32.8	128.5	1.0494	50.08	8.0	10.57	12.2	.2	.0	.0	.0	.0	.0	12.2	July 17, 1916	9.15	47.40	1.0490	8.4	8.94	.247
43	95	11.6	22.0	1.0207	6.329	22.0	July 19, 1916	9.15	32.5	128.5	1.0499	48.52	8.4	12.54	12.1	.3	.0	.0	.0	.....	.1	12.0	July 29, 1916	9.15	44.76	1.0472	10.4	10.14	.334
44	95	7.5	21.2	1.0203	6.011	20.2	Aug. 2, 1916	9.15	32.5	128.5	1.0509	48.72	9.0	10.02	12.1	.2	+.1	.0	.0	.....	.1	12.0	Aug. 7, 1916	9.15	45.72	1.0497	9.0	9.35	.228
45	95	8.7	20.0	1.0209	5.965	21.2	Aug. 23, 1916	9.15	32.5	128.5	1.0538	52.00	12.4	10.42	13.5	.5	.0	.0	.0	.....	.5	13.0	Aug. 28, 1916	9.15	51.08	1.0536	9.4	10.40	.0284
46	95	....	14.0	1.0186	5.772	16.0	Sept. 20, 1916	9.15	32.5	128.5	1.0490	48.88	10.0	9.955	12.5	.4	.0	.1	.0	.....	.4	12.1	Sept. 25, 1916	9.15	46.08	1.0497	13.4	9.579	.123
53	95	....	20.4	1.0198	6.115	18.4	Jan. 16, 1917	9.15	32.5	128.5	1.0499	85.76	14.8	10.520	12.2	.0	.0	+.1	.0	.....	.0	12.2	Jan. 22, 1917	9.15	47.80	1.0490	16.4	10.432	.067
54	95	....	19.2	1.0216	6.104	16.2	Jan. 25, 1917	9.15	32.5	128.5	1.0548	48.56	15.6	10.444	13.5	.2	+.1	.1	.0	.0	.3	13.2	Jan. 29, 1917	9.15	49.04	1.0536	18.0	10.032	.014
55	96	....	21.6	1.0200	6.141	17.3	Jan. 30, 1916	9.15	32.5	128.5	1.0420	36.64	11.4	10.552	10.5	.2	+.1	.1	.0	.0	.0	10.5	Feb. 5, 1917	9.15	38.80	1.0426	12.0	11.288	.216
43	96	11.6	22.0	1.0207	6.329	22.0	July 19, 1916	9.15	32.5	128.5	1.0559	93.12	8.0	8.08	13.7	1.1	.4	1.1	+.1	.....	2.5	11.2	July 29, 1916	9.15	91.52	1.0410	11.8	8.32	.259
44	96	7.5	21.2	1.0203	6.011	21.2	Aug. 2, 1916	9.15	32.5	128.5	1.0518	86.36	8.4	11.56	12.4	.3	2.8	1.5	1.3	.....	5.9	6.5	Aug. 7, 1916	9.15	29.08	1.0263	15.2	6.22	2.145
46	97	....	14.0	1.0186	5.772	16.0	Sept. 25, 1916	9.15	32.5	128.5	1.0495	77.52	9.2	10.354	11.9	3.7	1.2	.7	.1	.....	5.7	6.2	Sept. 25, 1916	9.15	23.08	1.0250	13.6	5.896	2.356
44	97	7.5	21.2	1.0203	6.011	21.2	Aug. 2, 1916	9.15	32.5	128.5	1.0549	82.80	8.0	11.78	13.2	1.6	1.3	2.6	+.1	.....	5.4	7.8	Aug. 7, 1916	9.15	31.84	1.0304	10.8	6.86	2.182
45	97	8.5	20.0	1.0209	5.965	21.2	Aug. 23, 1916	9.15	32.5	128.5	1.0569	82.64	10.4	12.39	14.1	1.6	1.0	.9	1.2	.....	4.6	9.5	Aug. 28, 1916	9.15	41.76	1.0376	14.8	8.16	2.029
46	97	....	14.0	1.0186	5.772	16.0	Sept. 20, 1916	9.15	32.5	128.5	1.0472	71.16	6.4	10.00	11.8	2.7	2.3	.0	.0	.....	5.2	6.6	Sept. 25, 1916	9.15	23.72	1.0264	9.2	5.94	1.890
49	97	....	22.8	1.0205	6.229	25.6	Nov. 21, 1916	9.15	32.5	128.5	1.0508	76.76	10.4	11.116	12.6	4.0	1.0	.7	.0	.....	5.7	6.9	Nov. 27, 1916	9.15	25.52	1.0297	13.2	6.716	2.199

50	97	....	21.6	1.0219	.....	22.4	Dec. 5, 1916	9.15	32.5	128.5	1.0472	73.04	9.6	11.032	12.1	.5	.1	.2	.0	.1	.8	11.3	Dec. 11, 1916	9.15	66.48	1.0440	10.4	6.236	.366
51	97	....	17.6	1.0149	5.842	14.0	Dec. 12, 1916	9.15	32.5	128.5	1.0523	77.40	11.6	10.488	12.8	3.8	.9	.8	.1	.1	5.6	7.2	Dec. 18, 1916	9.15	23.52	1.0288	11.8	6.604	2.185
52	97	....	17.6	1.0199	6.180	20.0	Jan. 9, 1917	9.15	32.5	128.5	1.0473	72.00	9.0	10.072	11.6	4.3	.6	.4	.2	.0	5.0	6.6	Jan. 15, 1917	9.15	26.12	1.0260	12.8	6.204	2.203
53	97	....	20.4	1.0198	6.115	18.4	Jan. 16, 1917	9.15	32.5	128.5	1.0548	46.92	10.8	12.688	13.5	1.5	2.5	1.1	.5	.....	5.6	7.9	Jan. 22, 1917	9.15	32.04	1.0324	16.6	7.652	2.460
54	97	....	19.2	1.0211	6.104	16.2	Jan. 25, 1917	9.15	32.5	128.5	1.0360	55.40	7.0	7.788	8.9	3.0	.6	.1	+.1	.2	3.6	5.3	Jan. 29, 1917	9.15	16.96	1.0206	11.2	4.552	1.646
45	99	8.7	20.0	1.0209	5.965	21.2	Aug. 23, 1916	9.15	32.5	128.5	1.0499	70.88	7.6	10.68	10.8	2.4	1.8	+.2	.0	.....	4.2	6.6	Aug. 28, 1916	9.15	26.50	1.0273	14.2	6.19	2.472
46	99	....	14.0	1.0186	5.772	16.0	Sept. 30, 1916	9.15	32.5	128.5	1.0507	72.16	8.0	10.39	11.6	3.1	1.5	.9	+.1	.....	5.4	6.2	Sept. 25, 1916	9.15	19.32	1.0276	8.0	5.865	2.482
49	99	....	22.8	1.0205	6.229	25.6	Nov. 21, 1916	9.15	32.5	128.5	1.0447	64.36	8.0	12.150	11.2	4.1	.7	.2	.3	.....	5.3	5.9	Nov. 27, 1916	9.15	16.56	1.0205	14.0	5.696	1.989
50	99	....	21.6	1.0219	.....	22.4	Dec. 3, 1916	9.15	32.5	128.5	1.0472	66.08	11.6	12.512	11.6	3.2	.7	1.1	.4	.....	5.4	6.2	Dec. 11, 1916	9.15	18.48	1.0240	12.4	5.720	28.26
45	100	8.7	20.0	1.0209	5.965	21.2	Aug. 26, 1916	9.15	32.5	128.5	1.0531	83.56	8.0	11.34	12.0	3.6	.7	1.2	.0	.....	5.5	6.5	Aug. 28, 1916	9.15	34.28	1.0269	10.8	6.46	2.785
46	100	....	14.0	1.0186	5.772	16.0	Sept. 20, 1916	9.15	32.5	128.5	1.0480	79.56	6.0	10.51	11.6	3.1	1.5	.9	+.1	.....	5.5	6.1	Sept. 25, 1916	9.15	24.80	1.0242	10.0	6.17	2.44
49	100	....	22.8	1.0205	6.229	25.6	Nov. 21, 1916	9.15	32.5	128.5	1.0528	87.56	7.8	11.110	12.9	3.5	1.9	.9	.2	.0	6.4	6.5	Nov. 25, 1916	9.15	26.16	1.0249	12.4	6.695	2.869
50	100	....	21.6	1.0219	.....	22.4	Dec. 3, 1916	9.15	32.5	128.5	1.0470	76.92	7.6	11.216	11.6	3.6	1.1	.9	.1	.1	5.7	5.9	Dec. 11, 1916	9.15	23.24	1.0230	12.4	5.800	2.745
51	100	....	17.6	1.0149	5.842	14.0	Dec. 12, 1916	9.15	32.5	128.5	1.0485	56.96	8.4	9.836	12.0	4.6	1.1	.1	.2	.....	6.0	6.0	Dec. 18, 1916	9.15	26.96	1.0233	11.2	5.896	2.537
52	100	7.3	17.6	1.0199	6.180	20.0	Jan. 9, 1917	9.15	32.5	128.5	1.0468	77.88	7.4	10.000	11.6	4.7	.7	.3	.1	.1	5.8	5.8	Jan. 15, 1917	9.15	25.84	1.0234	11.0	5.776	2.482
53	100	7.4	20.4	1.0198	6.115	18.4	Jan. 16, 1917	9.15	32.5	128.5	1.0618	97.92	10.8	16.304	14.8	4.0	2.0	.7	.2	.....	6.9	7.9	Jan. 22, 1917	9.15	34.40	1.0280	17.0	8.104	3.366
54	100	8.5	19.2	1.0216	6.104	16.2	Jan. 25, 1917	9.15	32.5	128.5	1.0417	68.60	7.0	9.072	10.5	4.5	.7	.0	.1	+.1	5.3	5.2	Jan. 29, 1917	9.15	20.76	1.0206	11.4	7.348	2.383
49	101	....	22.8	1.0205	6.229	25.6	Nov. 21, 1916	9.15	32.5	128.5	1.0448	88.60	7.2	11.048	11.1	4.2	1.1	.4	.1	.0	5.8	5.3	Nov. 27, 1916	9.15	33.68	1.0200	8.6	6.020	2.551
50	101	....	21.6	1.0219	.....	22.4	Dec. 3, 1916	9.15	32.5	128.5	1.0540	81.56	8.0	13.400	13.0	4.4	1.6	.8	.0	.1	6.8	6.2	Dec. 11, 1916	9.15	41.68	1.0230	11.2	6.872	2.368
51	101	....	17.6	1.0149	5.842	14.0	Dec. 12, 1916	9.15	32.5	128.5	1.0461	87.88	8.0	13.016	11.4	4.4	1.1	.2	.1	.0	5.8	5.6	Dec. 18, 1916	9.15	36.24	1.0197	8.8	5.960	2.241
52	101	7.3	17.6	1.0199	6.180	20.0	Jan. 9, 1917	9.15	32.5	128.5	1.0368	74.32	5.8	8.936	9.8	4.5	.4	+.1	.3	.1	5.1	4.7	Jan. 15, 1917	9.15	30.16	1.0168	9.6	7.412	2.156
53	101	7.4	20.4	1.0198	6.115	18.4	Jan. 16, 1917	9.15	32.5	128.5	1.0500	101.84	8.2	13.616	13.1	3.8	1.8	.5	.3	.....	6.4	6.7	Jan. 22, 1917	9.15	44.52	1.0240	15.2	7.788	3.049
54	101	8.5	19.2	1.0216	6.104	16.2	Jan. 25, 1917	9.15	32.5	128.5	1.0587	105.84	3.2	13.964	13.6	4.9	1.5	1.2	+1.0	.2	6.6	7.0	Jan. 29, 1917	9.15	45.08	1.0279	13.8	7.264	3.197
55	101	6.5	21.6	1.0200	6.141	17.3	Jan. 30, 1917	9.15	32.5	128.5	1.0675	104.32	10.8	12.928	16.3	3.6	2.7	1.1	.5	.2	7.9	8.4	Feb. 5, 1917	9.15	59.56	1.0542	15.4	9.760	3.478
49	102	....	22.8	1.0205	6.229	25.6	Nov. 21, 1916	9.15	32.5	128.5	1.0472	95.28	9.2	12.099	11.4	3.4	1.5	.1	.1	.0	5.1	6.3	Nov. 27, 1916	9.15	43.00	1.0209	13.2	7.264	2.286
50	102	....	21.6	1.0219	.....	22.4	Dec. 3, 1916	9.15	32.5	128.5	1.0460	90.44	10.0	11.892	11.3	3.7	1.2	.3	.0	.1	5.2	6.1	Dec. 11, 1916	9.15	42.88	1.0243	11.2	7.216	2.368
51	102	....	17.6	1.0149	5.842	14.0	Dec. 12, 1916	9.15	32.5	128.5	1.0510	98.68	8.8	12.064	12.2	1.9	2.1	1.3	.0	.0	5.3	6.9	Dec. 18, 1916	9.15	41.76	1.0274	10.4	7.696	2.355
52	102	7.3	17.6	1.0199	6.180	20.0	Jan. 9, 1917	9.15	32.5	128.5	1.0574	103.52	14.0	14.636	13.9	1.1	1.6	1.9	1.3	.5	5.9	8.0	Jan. 15, 1917	9.15	54.08	1.0320	16.0	9.276	2.849
53	102	7.4	20.4	1.0198	6.115	18.4	Jan. 16, 1917	9.15	32.5	128.5	1.0512	100.56	13.2	13.924	13.0	2.8	1.3	1.3	.3	.....	5.4	7.6	Jan. 22, 1917	9.15	48.96	1.0277	17.2	8.652	2.545
54	102	8.5	19.2	1.0216	6.104	16.2	Jan. 25, 1917	9.15	32.5	128.5	1.0587	103.76	11.6	14.424	14.1	1.9	2.6	1.4	.2	.2	6.1	8.0	Jan. 29, 1917	9.15	49.72	1.0320	20.4	8.792	2.676
49	103	....	22.8	1.0205	6.229	25.6	Nov. 21, 1916	9.15	32.5	128.5	1.0457	65.56	10.4	9.699	11.3	3.1	1.8	.3	.0	.0	5.2	6.1	Nov. 27, 1916	9.15	17.56	1.0219	11.2	5.776	2.255
50	103	....	21.6	1.0219	.....	22.4	Dec. 3, 1916	9.15	32.5	128.5	1.0700	98.48	16.6	14.87	17.2	3.3	+.1	1.2	2.1	.8	6.5	10.7	Dec. 11, 1916	9.15	34.72	1.0444	20.0	10.000	2.521
51	103	....	17.6	1.0149	5.842	14.0	Dec. 12, 1916	9.15	32.5	128.5	1.0426	60.00	8.8	8.596	10.5	3.8	.7	.1	.1	.1	4.7	5.8	Dec. 18, 1916	9.15	16.56	1.0220	13.2	5.236	2.004
52	103	7.3	17.6	1.0199	6.180	20.0	Jan. 9, 1917	9.15	32.5	128.5	1.0459	67.28	11.9	10.412	11.6	4.4	.7	+.4	+.2	.1	5.3	6.3	Jan. 15, 1917	9.15	32.12	1.0245	16.2	5.924	2.306
53	103	7.4	20.4	1.0195	6.115	18.4	Jan. 16, 1917	9.15	32.5	128.5	1.0483	71.28	13.6	11.036	12.3	4.0	1.1	1.4	.7	.....	5.6	6.7	Jan. 22, 1917	9.15	21.44	1.0250	17.8	6.512	2.416
54	103	8.5	19.2	1.0216	6.104	16.2	Jan. 25, 1917	9.15	32.5	128.5	1.0516	73.64	12.0	10.272	12.4	4.5	.9	.2	+.1	.1	5.5	6.9	Jan. 29, 1917	9.15	20.52	1.0218	19.6	6.280	2.402
55	103	6.5	21.6	1.0200	6.141	17.3	Jan. 30, 1917	9.15	32.5	128.5	1.0707	97.36	18.6	11.408	17.2	3.0	2.1	2.1	.2	.4	7.4	9.8	Feb. 5, 1917	9.15	34.44	1.0398	25.0	9.672	3.195
49	104	....	22.8	1.0205	6.229	25.6	Nov. 21, 1916	9.15	32.5	128.5	1.0520	91.28	10.6	11.032	12.6	4.2	1.0	.6	.5	.1	6.3	6.3	Nov. 27, 1916	9.15	33.20	1.0249	16.2	6.504	2.802
50	104	....	21.6	1.0219	.....	22.4	Dec. 3, 1916	9.15	32.5	128.5	1.0183	104.24	14.8	17.792	19.4	3.4	.3	2.1	1.1	1.7	6.9	12.5	Dec. 11, 1916	9.15	67.44	1.0512	28.3	12.304	3.107
51	104	....	17.6	1.0149	5.842	14.0	Dec. 12, 1916	9.15	32.5	128.5	1.0483	83.52	10.0	10.112	11.8	4.3	1.2	.5	+.1	.0	5.9	5.9	Dec. 18, 1916	9.15	29.68	1.0220	10.2	5.760	2.630
52	104	7.3	17.6	1.0199	6.180	20.0	Jan. 9, 1917	9.15	32.5	128.5	1.0490	86.72	12.2	11.376	12.2	5.1	.7	.1	.2	.0	6.1	6.1	Jan. 15, 1917	9.15	19.00	1.0245	14.8	6.096	2.641
53	104	7.4	20.4	1.0198	6.115	18.4	Jan. 16, 1917	9.15	32.5	128.5	1.0573	89.72	14.2	13.428	13.8	3.7	1.8	.9	+.1	.....	6.3	7.5	Jan. 22, 1917	9.15	38.96	1.0268	19.2	7.576	3.179
54	104	8.5	19.2	1.0216	6.104	16.2	Jan. 25, 1917	9.15	32.5	128.5	1.0519	93.16	10.8	11.220	12.6	4.6	1.2	.2	+.1	.2	5.9	6.7	Jan. 29, 1917	9.15	32.56	1.0260	17.2	5.992	2.916
55	104	6.5	21.6	1.0200	6.141	17.3	Jan. 30, 1917	9.15	32.5	128.5	1.0493	88.36	9.2	10.936	12.3	4.6	1.4	.4	+.2	+.1	6.2	6.1	Feb. 5, 1917	9.15	32.36	1.0248	17.0	6.536	2.674
51	107	7.4	17.6	1.0149	5.842	14.0	Dec. 12, 1916	9.15	32.5	128.5	1.0505	54.00	4.4	8.816	12.3	2.1	.4	.8	.0	.0	3.3	9.0	Dec. 18, 1916	9.15	20.48	1.0338	7.4	6.26	1.699
52	107	7.3	17.6	1.0199	6.180	20.0	Jan. 9, 1917	9.15	32.5	128.5	1.0479	52.40	4.8	8.940	11:5	2.7	.1	.1	.4	.2	3.3	8.2	Jan. 15, 1917	9.15	21.56	1.0342	7.6	6.176	1.677
51	108	7.4	17.6	1.0149	5.842	14.0	Dec. 12, 1916	9.15	32.5	128.5	1.0548	86.72	5.2	10.852	13.3	3.3	.8	1.1	+.2	.0	5.1	8.2	Dec. 18, 1916	9.15	34.28	1.0325	14.0	7.160	2.166
52	108	7.3	17.6	1.0199	6.180	20.0	Jan. 9, 1917	9.15	32.5	128.5	1.0528	83.16	8.2	......	12.8	4.5	.6	+.1	.1	+.1	5.2	7.6	Jan. 15, 1917	9.15	35.64	1.0325	11.2	7.224	2.365
53	108	7.4	20.4	1.0198	6.115	18.4	Jan. 16, 1917	9.15	32.5	128.5	1.0480	97.28	8.0	12.612	13.6	3.8	1.0	.3	.0	.....	5.1	8.5	Jan. 22, 1917	9.15	37.60	1.0333	12.4	7.884	2.115
54	108	8.5	19.2	1.0216	6.104	16.2	Jan. 25, 1917	9.15	32.5	128.5	1.0547	85.88	6.0	11.62	13.1	4.0	.4	.4	.1	.1	4.9	8.2	Jan. 29, 1917	9.15	33.80	1.0333	12.0	6.988	2.330
55	108	6.5	21.6	1.0200	6.141	17.3	Jan. 30, 1917	9.15	32.5	128.5	1.0665	49.72	8.0	14.48	16.2	3.0	2.5	.6	.1	.1	6.2	10.0	Feb. 5, 1917	9.15	45.24	1.0408	12.6	9.792	4.585

TABLE 3.—*Fermentation record*—Continued.

Fermentation No.	Cook No.	Yeast. Seed yeast. Brix.	Yeast. Seed yeast. Acidity.	Yeast. 96-hour yeast. Sp. gr. at 15° C.	Yeast. 96-hour yeast. Alcohol (per cent by weight).	Yeast. 96-hour yeast. Acidity.	Fermenter set. Date.	Fermenter set. Hour.	Hours filling fermenter.	Hours fermenting, including time of filling.	Mash before fermentation. Sp. gr. at 15° C.	Mash before fermentation. Reducing sugars (grams per liter).	Mash before fermentation. Acidity.	Mash before fermentation. Total solids (per cent).	Mash before fermentation. Brix.	Brix record (decrease in Brix). First day.	Brix record (decrease in Brix). Second day.	Brix record (decrease in Brix). Third day.	Brix record (decrease in Brix). Fourth day.	Brix record (decrease in Brix). Fifth day.	Attenuation (degrees).	Beer. Brix fourth day.	Beer. Distillation. Date.	Beer. Distillation. Hour.	Beer. Reducing sugars (grams per liter).	Beer. Sp. gr. at 15° C.	Beer. Acidity.	Beer. Total solids (per cent by weight).	Beer. Alcohol (per cent by weight).
								a. m.																a. m.					
10	51-1	....	....	1.0243	6.170	18.6	Jan. 21, 1915	9.15	32.5	128.5	1.0502	62.28	6.2	9.069	12.2	2.6	1.0	1.0	1.0	0.4	4.6	7.6	Jan 26, 1915	9.15	17.40	1.0262	12.0	5.744	1.910
11	51-1	....	22.0	1.0262	5.398	26.4	Feb. 11, 1915	9.15	32.5	128.5	1.0508	61.70	2.4	10.520	12.5	3.6	1.4	.3	.2	.....	5.5	7.0	Feb. 16, 1915	9.15	11.74	1.0280	9.6	6.195	2.267
10	51-2	....	....	1.0243	6.170	18.6	Jan. 21, 1915	9.15	32.5	128.5	1.0482	61.56	4.4	8.824	11.9	3.6	1.3	.2	.1	.0	5.2	6.7	Jan. 26, 1915	9.15	11.88	1.0277	11.2	5.996	2.233
11	51-2	....	22.0	1.0262	5.398	26.4	Feb. 11, 1915	9.15	32.5	128.5	1.0509	66.04	4.4	11.470	12.5	3.8	1.5	.3	.0	.....	5.6	6.9	Feb. 16, 1915	9.15	11.74	1.0270	10.4	6.327	2.313
10	51-3	....	....	1.0243	6.170	18.6	Jan. 21, 1915	9.15	32.5	128.5	1.0492	59.52	6.4	9.100	12.1	3.6	1.3	.1	.1	.0	5.1	7.0	Jan. 26, 1915	9.15	17.08	1.0273	12.5	6.019	2.171
11	51-3	....	22.0	1.0262	5.398	26.4	Feb. 11, 1915	9.15	32.5	128.5	1.0480	60.24	6.0	9.927	11.8	3.6	1.1	.4	.0	.....	5.1	6.7	Feb. 16, 1915	9.15	15.00	1.0269	11.2	6.165	2.152
10	51-4	....	....	1.0243	6.170	18.6	Jan. 21, 1915	9.15	32.5	128.5	1.0486	62.12	3.6	9.104	12.0	3.7	1.1	.2	.0	.0	5.0	7.0	Jan. 26, 1915	9.15	18.52	1.0286	11.4	6.653	2.129
11	51-4	....	22.0	1.0262	5.398	26.4	Feb. 11, 1915	9.15	32.5	128.5	1.0521	68.704	4.0	11.580	12.7	3.7	1.2	.3	.1	.....	5.3	7.4	Feb. 16, 1915	9.15	18.88	1.0296	9.6	7.156	2.360
10	51-5	....	....	1.0243	6.170	18.6	Jan. 21, 1915	9.15	32.5	128.5	1.0488	57.28	2.4	9.305	12.1	3.0	1.0	.2	.0	.1	4.2	7.9	Jan. 26, 1915	9.15	17.86	1.0304	10.4	6.237	1.844
11	51-5	....	22.0	1.0262	5.398	26.4	Feb. 11, 1915	9.15	32.5	128.5	1.0532	62.28	3.8	11.765	13.0	3.2	1.0	.4	.1	.....	4.6	8.4	Feb. 16, 1915	9.15	18.92	1.0338	10.0	7.709	1.949
12	53-d	....	....	1.0270	5.574	27.0	Mar. 4, 1915	9.15	32.5	128.5	1.0515	62.376	3.9	10.039	12.3	2.3	1.8	.4	.4	.....	3.9	8.4	Mar. 9, 1915	9.15	23.52	1.0337	12.0	7.030	1.625
13	53-d	....	19.8	1.0309	5.510	30.2	Mar. 11, 1915	9.15	32.5	128.5	1.0506	61.92	8.0	9.850	12.2	2.9	1.8	.4	.1	.....	5.2	7.0	Mar. 16, 1915	9.15	10.84	1.0284	12.2	5.905	2.188
12	53-1	....	....	1.0270	5.574	27.0	Mar. 4, 1915	9.15	32.5	128.5	1.0497	62.12	3.8	9.870	12.3	1.6	+ .2	− .1	.1	.....	1.4	10.9	Mar. 9, 1915	9.15	44.70	1.0422	7.0	8.500	.648
13	53-1	....	19.8	1.0390	5.510	30.2	Mar. 11, 1915	9.15	32.5	128.5	1.0460	55.12	6.8	8.948	11.4	2.1	.1	.0	.0	.....	2.2	9.2	Mar. 16, 1915	9.15	33.86	1.0367	8.0	6.859	.897
12	53-2	....	....	1.2070	5.574	27.0	Mar. 4, 1915	9.15	32.5	128.5	1.0473	57.08	3.6	9.328	11.6	2.6	.7	.7	.0	.....	4.0	7.6	Mar. 9, 1915	9.15	18.72	1.0298	10.8	6.220	1.690
13	53-2	....	19.8	1.0309	5.510	30.2	Mar. 11, 1915	9.15	32.5	128.5	1.0510	63.92	9.4	10.120	12.6	3.3	1.7	.3	.1	.....	4.4	7.2	Mar. 16, 1915	9.15	11.74	1.0284	12.4	6.054	2.266
12	53-3	....	....	1.0270	5.574	27.0	Mar. 4, 1915	9.15	32.5	128.5	1.0495	59.52	3.7	9.660	12.1	3.2	1.6	.2	.1	.....	5.1	7.0	Mar. 9, 1915	9.15	10.04	1.0275	12.1	6.000	2.087
13	53-3	....	19.8	1.0390	5.510	30.2	Mar. 11, 1915	9.15	32.5	128.5	1.0520	61.96	8.8	10.125	12.6	1.4	.2	.6	.3	.....	2.5	10.1	Mar. 16, 1915	9.15	35.30	1.0401	11.8	7.491	1.019
12	53-4	....	....	1.0270	5.574	27.0	Mar. 4, 1915	9.15	32.5	128.5	1.0508	57.74	4.3	9.970	12.4	3.4	1.3	.3	.1	.....	5.1	7.3	Mar. 9, 1915	9.15	10.68	1.0287	12.8	6.293	2.090
13	53-4	....	19.8	1.0309	5.510	30.2	Mar. 11, 1915	9.15	32.5	128.5	1.0502	57.34	9.2	9.670	12.1	1.3	1.6	1.1	.5	.....	4.5	7.6	Mar. 12, 1915	9.15	12.36	1.0299	12.4	6.192	1.913
12	53-5	....	....	1.0270	5.574	27.0	Mar. 4, 1915	9.15	32.5	128.5	1.0515	54.76	3.9	9.940	12.6	2.5	1.0	.7	.3	.....	4.5	8.1	Mar. 9, 1915	9.15	13.12	1.0321	12.9	6.700	1.836
13	53-5	....	19.8	1.0309	5.510	30.2	Mar. 11, 1915	9.15	32.5	128.5	1.0388	58.34	8.6	10.260	13.1	1.0	.3	.1	.1	.....	11.6	1.5	Mar. 16, 1915	9.15	41.16	1.0475	11.4	8.654	.549
14	53-5	....	22.5	1.0235	5.784	24.5	Mar. 18, 1915	9.15	32.5	128.5	1.0504	53.22	8.0	8.881	12.4	.6	.5	1.4	1.7	.4	4.2	8.2	Mar. 23, 1915	9.15	15.24	1.0329	12.4	6.679	1.646
12	53-6	....	....	1.0270	5.574	27.0	Mar. 4, 1915	9.15	32.5	128.5	1.0456	32.52	3.3	10.660	13.2	2.8	1.4	.3	.1	.....	4.6	8.6	Mar. 9, 1915	9.15	7.84	1.0343	12.2	7.127	2.016
13	53.6	....	19.8	1.0309	5.510	30.2	Mar. 11, 1915	9.15	32.5	128.5	1.0490	47.38	4.4	9.364	12.0	3.1	1.0	.2	+ .1	.....	4.2	7.8	Mar. 16, 1915	9.15	8.14	1.0308	11.0	6.380	1.790
14	53-6	....	22.5	1.0235	5.784	24.5	Mar. 18, 1915	9.15	32.5	128.5	1.0515	49.56	6.0	9.204	12.5	3.0	1.2	.2	.0	.....	4.4	8.1	Mar. 23, 1915	9.15	8.28	1.0324	10.0	6.702	1.951
12	53-7	....	....	1.0270	5.574	27.0	Mar. 4, 1915	9.15	32.5	128.5	.0576	53.04	4.1	11.349	13.9	3.0	1.0	.3	.2	.....	4.5	9.4	Mar. 9, 1915	9.15	8.48	1.0371	12.4	7.850	1.851
13	53-7	....	19.8	1.0309	5.510	30.2	Mar. 11, 1915	9.15	32.5	128.5	1.0496	46.192	3.8	9.583	12.2	3.0	.8	.1	.1	.....	4.0	8.2	Mar. 16, 1915	9.15	8.00	1.0326	11.2	6.674	1.724
14	53-7	....	22.5	1.0235	5.784	24.5	Mar. 18, 1915	9.15	32.5	128.5	1.0481	43.76	6.4	8.639	11.7	2.7	.9	.1	.0	.....	3.7	8.0	Mar. 23, 1915	9.15	7.78	1.0314	11.0	6.456	1.682
14	53-8	....	22.5	1.0235	5.784	24.5	Mar. 18, 1915	9.15	32.5	128.5	1.0547	47.32	3.6	10.061	2.3	1.3	.3	.1	.1	.....	4.0	9.4	Mar. 23, 1915	9.15	9.00	1.0380	12.0	7.780	1.772
15	53-8	14.7	....	1.0224	6.113	17.4	Mar. 26, 1915	9.15	32.5	128.5	1.0519	44.144	6.6	8.785	12.6	2.6	.8	.2	.1	.1	3.7	8.9	Mar. 31, 1915	9.15	8.52	1.0357	10.8	7.311	1.685
16	53-8	13.9	18.5	1.0223	6.167	26.2	Apr. 1, 1915	9.15	32.5	128.5	1.0489	42.46	6.4	9.0 5	12.1	2.7	.7	.2	.1	.....	3.7	8.4	Apr. 6, 1915	9.15	7.56	1.0338	12.0	6.914	1.610

TABLE 4.—*Digester record.*

Species of wood.	Cook No.	Cooking conditions.							Digester charge.				Digester discharge.					Sugar yield.							
		Minutes to reach desired pressure.	Cooking pressure (atmospheres).	Time cooked (minutes).	Maximum temperature during cook (° F.).	Total time steam on digester (minutes).	Blow-off treatment.	Time required for blow-off (minutes).	Water to wood ratio (per cent).	Acid (100 per cent) to wood ratio (per cent).	Dry weight of wood charged (pounds).	Moisture in wood as charged.	Digested sawdust (pounds).	Digested liquor (pounds).	Moisture in digested sawdust (per cent).	Dry weight digested sawdust (pounds).	Original wood obtained as digested sawdust (per cent).	Reducing sugars in digested sawdust (per cent).	Reducing sugars in digested liquor (grams per liter).	Reducing sugars (per cent of dry digested sawdust).	Reducing sugars (per cent of original dry wood).	Reducing sugars dry digested sawdust compared with original dry wood.	Total soluble solids (per cent original dry wood).	Total reducing sugars (per cent of total soluble solids).
White spruce	21	28.5	7.5	0	.....	28.5	Cond.	73	300	1.85	98.65	17.89	204.45	98.03 144.55	61.44	78.84	79.91	4.152	61.16 60.84	22.98	23.16	125.13	28.21	82.08
	22	21.0	7.5	0	.....	21.0	...do..	80	250	1.82	103.25	14.78	207.74	99.86 89.75	59.83	83.45	80.82	5.104	75.28 77.36	29.39	23.75	123.75	28.23	84.13
	23	13.5	[1] 115	10	.....	23.5	...do..	90	112	1.40	98.78	18.63	271.11	.....	65.78	92.77	93.92	8.544	.....	25.07	23.55	106.45	25.85	91.10
	24	22.5	[1] 110	10	.....	22.5	Open.	.....	127	1.84	110.22	10.92	322.85	.....	68.81	100.70	91.36	8.161	.....	26.06	23.81	109.45	28.00	85.04
	25	17.0	[1] 110	10	.....	17.0	...do..	.....	100	1.83	103.07	10.96	271.45	.....	64.78	95.60	92.76	9.496	.....	26.96	25.01	107.80	26.28	95.17
	26	20.0	7.5	0	.....	20.0	Cond.	75	400	1.80	103.24	10.30	213.93	163.44 97.82 31.34	60.50	84.50	81.85	3.556	51.56 52.76 56.84	27.17	22.24	122.17	34.22	64.99
Shortleaf pine	27	19.0	[1] 115	10	.....	19.0	Open.	8	127	1.80	98.80	33.96	264.90	25.06	66.44	88.90	89.98	5.816	84.80	20.64	18.57	111.15	19.63	94.60
	28	19.0	7.5	0	345	19.0	Cond.	72	400	1.80	99.53	32.22	207.71	268.78 93.95	53.68	96.21	96.66	0.696	10.70 11.02	5.52	5.34	103.3	14.04	38.03
	29	19.5	7.5	10	346	29.5	...do..	110	250	1.80	97.65	30.03	190.38	130.51 91.42	55.32	85.06	87.11	2.864	47.76 47.60	18.79	16.37	114.78	23.22	70.50
White spruce	30	20.25	7.5	0	346	20.2	...do..	75	100	1.80	103.55	9.94	271.20	.....	64.19	97.12	93.79	8.049	.....	22.49	21.09	106.64	25.77	81.84
	31	19.5	7.5	0	345	19.5	...do..	80	125	2.50	102.08	9.105	290.93	.....	68.87	90.57	88.72	7.524	.....	24.18	21.45	112.73	23.48	91.35
	32	20.25	7.5	10	346	30.2	...do..	93	125	2.50	108.60	8.74	316.64	.....	69.45	96.73	89.07	7.312	.....	23.94	21.32	112.29	21.32	100.00
	33	20.25	7.5	0	344	20.2	...do..	71	125	1.40	108.07	8.47	304.96	.....	66.71	101.52	93.94	8.021	.....	24.66	23.17	106.43	24.13	96.02
	34	20.5	7.5	0	340	20.5	...do..	99	125	1.80	100.68	9.15	288.06	.....	67.37	93.99	93.36	7.675	.....	23.52	21.96	107.10	23.12	94.98
	35	20.0	7.5	0	243	20.0	...do..	92	125	1.00	97.53	8.725	281.51	.....	67.21	92.31	94.64	7.516	.....	22.91	21.68	105.67	25.99	83.42
	36	19.5	7.5	0	341	19.5	...do..	103	125	4.00	99.52	8.54	284.85	.....	69.47	86.96	87.38	7.408	.....	24.15	21.10	114.45	26.99	78.18
	37	20.75	7.5	0	343	20.7	...do..	94	125	.75	102.21	8.59	288.93	.....	66.40	97.08	94.98	7.616	.....	22.98	21.83	105.36	24.00	90.96
	38	19.5	7.5	0	341	19.5	...do..	73	125	.50	99.95	8.83	288.05	.....	66.30	97.07	97.12	6.044	.....	17.94	17.42	102.98	23.20	75.08
	39	19.25	7.5	0	341	19.2	Open.	8	125	1.40	102.35	8.85	285.00	.....	65.01	99.72	97.43	8.033	.....	22.96	22.37	102.64	25.37	88.18
	40	18.5	7.5	0	340	18.5	Cond.	65	125	1.40	101.98	10.69	293.47	.....	66.25	99.05	97.12	8.216	.....	24.44	23.74	102.95	27.40	86.64
	41	20.5	7.5	10	340	30.5	...do..	65	125	1.40	102.94	9.52	296.61	.....	67.52	96.34	93.59	8.009	.....	24.67	23.09	106.84	26.48	87.20
	42	20.0	7.5	30	340	50.0	...do..	90	125	1.40	115.89	10.59	343.85	.....	69.00	106.59	91.98	7.524	.....	24.28	22.34	108.68	23.91	93.43
	43	23.0	7.5	0	340	23.0	...do..	60	100	1.40	118.54	10.95	300.59	.....	62.93	111.43	94.00	8.604	.....	23.23	21.84	106.36	26.65	81.95
	44	20.75	7.5	0	337	20.7	...do..	60	200	1.40	101.14	10.42	368.61	.....	73.48	97.76	96.65	6.308	.....	23.80	23.00	103.48	26.06	88.26

[1] Pounds.

TABLE 4.—*Digester record*—Continued.

Species of wood.	Cook No.	Cooking conditions.							Digester charge.				Digester discharge.					Sugar yield.							
		Minutes to reach desired pressure.	Cooking pressure (atmospheres).	Time cooked (minutes).	Maximum temperature during cook (° F.).	Total time steam on digester (minutes).	Blow-off treatment.	Time required for blow-off (minutes).	Water to wood ratio (per cent).	Acid (100 per cent) to wood ratio (per cent).	Dry weight of wood charged (pounds).	Moisture in wood as charged.	Digested sawdust (pounds).	Digested liquor (pounds).	Moisture in digested sawdust (per cent).	Dry weight digested sawdust (pounds).	Original wood obtained as digested sawdust (per cent).	Reducing sugars in digested sawdust (per cent).	Reducing sugars in digested liquor (grams per liter).	Reducing sugars (per cent of dry digested sawdust).	Reducing sugars (per cent of original dry wood).	Reducing sugars dry digested sawdust compared with original dry wood.	Total soluble solids (per cent original dry wood).	Total reducing sugars (per cent of total soluble solids).
White spruce—(Con.)	45	20.0	7.5	0	337	20.0	Cond.	70	125	2.50	103.38	10.59	298.83	.....	66.25	100.86	97.56	7.888	.....	23.34	22.77	102.50	29.14	78.14
	46	20.0	7.5	20	338	40.0	...do..	85	125	2.50	103.20	11.04	306.02	.....	69.71	92.64	89.82	7.916	.....	26.29	23.61	111.35	29.06	81.24
	47	19.0	7.5	10	336	29.0	...do..	72	125	2.50	97.54	10.00	294.83	.....	69.37	90.31	92.58	7.704	.....	25.28	23.40	108.03	23.91	97.87
Shortleaf pine	48	20.5	7.5	10	336	30.5	...do..	73	125	2.50	95.90	11.90	295.12	.....	67.35	96.36	100.48	5.572	.....	17.07	17.15	99.53	21.31	80.48
	49	19.5	7.5	10	336	29.5	...do..	83	125	4.00	91.64	12.04	283.42	.....	67.78	91.32	99.65	4.500	.....	14.07	14.02	100.35	21.45	65.36
Western larch	50	20.0	7.5	10	332	30.0	...do..	75	125	1.80	113.09	21.375	292.01	65.05	68.89	90.84	80.33	8.976	119.84	37.00	29.72	124.50	35.18	84.48
White spruce	51	21.0	7.5	15	336	36.0	None.	290	125	2.50	169.76	8.80	477.30	25.00	70.92	138.79	81.76	4.360	127.60	17.18	14.05	122.28	26.82	63.06
	52	21.0	7.5	15	.....	36.0	...do..	.....	125	2.50	167.55	7.95	468.38	.....	68.53	147.40	87.97	9.227	.....	29.50	25.95	113.68	32.73	79.29
	53	20.0	7.5	15	.....	36.0	...do..	.....	125	2.50	168.43	10.22	501.40	.....	70.71	146.86	87.19	5.696	.....	19.58	17.07	114.70	21.97	77.68
	54	20.0	7.5	15	.....	35.0	...do..	.....	125	2.50	159.83	8.98	469.91	153.67	62.90	174.34	109.07	4.944	67.46	19.13	20.87	91.66	32.91	63.42
	55	19.0	7.5	90	.....	109.0	Cond.	104	125	2.50	104.22	9.615	314.68	44.82	72.28	87.23	83.70	5.406	67.32	21.58	18.06	119.49	22.14	81.57
	56	19.0	7.5	45	.....	64.0	...do..	75	125	2.50	108.30	9.85	354.68	.....	74.15	91.68	84.66	6.575	.....	25.78	21.56	119.57	23.66	91.12
	57	20.0	9.0	15	.....	35.0	...do..	95	125	2.50	99.55	10.075	319.38	.....	72.92	86.49	86.88	6.574	.....	24.26	21.08	115.09	22.50	93.69
	58	20.0	6.0	15	.....	35.0	...do..	45	125	2.50	107.87	9.32	330.73	.....	69.53	100.77	93.42	7.460	.....	24.43	22.82	106.86	21.75	104.92
White spruce (fine chips).	59	20.0	7.5	15	.....	35.0	...do..	75	125	2.50	98.18	9.81	333.47	.....	82.08	59.76	60.86	5.931	.....	33.21	20.21	164.32	21.62	93.47
White spruce (large chips).	60	20.0	7.5	115	.....	35.0	...do..	84	125	2.50	101.40	9.64	294.53	35.44	71.19	84.85	83.68	6.090	70.76	25.10	21.005	119.50	21.19	99.13
White spruce (dust and chips).	61	20.0	7.5	15	.....	35.0	...do..	60 to 120	125	2.50	101.50	9.28	329.43	.....	70.3	97.9	96.2	6.719	.....	22.6	21.75	103.9	23.50	96.2
Birch	62	20.0	7.5	20	332	40.0	...do..		125	2.50	72.87	9.18	124.0	104.0	58.8	51.1	70.1	5.256	80.70	29.3	20.53	142.8	21.36	96.4
Western white pine	63	20.0	7.5	20	310	40.5	...do..		125	2.50	106.48	9.55	315.58	.....	69.85	95.1	89.4	7.088	.....	23.5	21.00	112.0	23.81	88.2
Red spruce	64	20.5	7.5	20.5	327	41	...do..	.....	125	2.50	100.60	10.55	308.89	.....	72.63	73.7	73.2	6.670	.....	28.0	20.48	136.4	18.20	88.9
Douglas fir, Montana.	65	18	7.5	20	330	38	...do..	.....	125	2.50	135.71	31.41	385.59	.....	67.87	123.9	91.4	7.428	.....	23.1	21.10	109.6	26.63	79.2
White pine	66	20	7.5	20	330	40	...do..	.....	125	2.50	93.08	9.32	288.11	.....	72.63	78.9	84.8	6.468	.....	23.6	20.02	118.0	21.08	95.1
Longleaf pine	67	20	7.5	19.5	300	39.5	...do..	.....	125	2.50	104.83	48.30	298.64	.....	62.04	113.3	[3] 108.2	8.090	.....	21.3	23.06	92.5	31.65	74.0
	68	20	7.5	20	329	40	...do..	.....	125	2.50	108.60	45.53	309.80	.....	60.89	121.0	129.9	8.150	.....	17.9	23.25	77.0	23.46	99.1
Lodge pole pine	69	20	7.5	20	328	40	...do..	.....	125	2.50	126.52	18.92	366.05	.....	70.19	109.15	86.3	7.580	.....	25.4	21.93	115.7	24.05	91.0
Norway pine (chips).	70	20	7.5	20	332	40	...do..	.....	125	2.50	66.52	10.62	108.52	227.87	52.05	56.50	84.9	3.816	58.68	30.1	25.62	117.3	21.10	82.4

Red spruce	71	22	7.5	20	330	42	...do..	.....	125	2.50	101.83	9.45	313.95	.....	68.40	99.20	92.4	7.156	.....	23.9	22.06	108.2	23.40	94.3
Western larch	72	20	7.5	20	332	40	...do..	.....	125	2.50	128.93	12.72	383.23	.....	66.65	127.95	92.0	8.818	.....	27.7	25.44	108.8	31.71	80.3
Hard maple	73	21	7.5	20	328	41	...do..	.....	125	2.50	110.10	9.39	198.75	123.38	56.70	86.0	78.0	5.442	85.17	24.3	18.93	128.3	20.38	93.0
Douglas fir, coast	74	19	7.5	20	326	39	...do..	.....	125	2.50	124.95	16.06	355.57	.....	68.52	112.0	89.7	7.424	.....	23.5	21.13	111.4	21.25	99.3
Silver maple	75	20	7.5	20	326	40	...do..	.....	125	2.50	93.20	9.36	295.58	.....	73.40	78.5	84.0	6,540	.....	24.7	20.74	118.6	21.65	95.5
Beech	76	20	7.5	22.5	330	42.5	...do..	.....	125	2.50	53.94	9.97	203.66	115.0	57.06	38.65	71.7	4.190	69.41	29.6	21.24	139.1	23.15	91.7
White Oak	77	20.5	7.5	22	322	42.5	...do..	.....	125	2.50	153.13	9.72	351.52	66.87	63.45	128.4	83.3	6.040	82.35	20.7	17.30	116.0	21.43	80.8
Red oak	78	19	7.5	20	328	39	...do..	.....	125	2.50	102.22	9.26	162.50	135.79	55.99	71.5	69.9	5,525	75.27	26.3	18.38	143.1	19.47	95.1
Sycamore	79	20	7.5	20	329	40	...do..	.....	125	2.50	96.41	9.58	159.46	254.54	57.13	100.0	103.7	3,216	50.72	17.7	18.30	97.0	24.40	75.0
Slippery elm	80	21	7.5	20	330	41	...do..	.....	125	2.50	61.75	10.48	186.89	42.62	71.55	53.1	86.1	4,548	67.24	19.3	16.60	116.1	23.95	69.4
Red gum	81	20	7.5	20	327	40	...do..	.....	125	2.50	100.10	45.72	277.77	26.40	69.76	84.0	83.9	6.522	93.90	24.4	20.42	119.0	21.75	93.9
Cottonwood	82	20	7.5	20	323	40	...do..	.....	125	2.50	92.31	13.87	277.96	.....	67.35	90.7	98.4	6,040	.....	18.5	18.19	101.7	23.38	77.8
Western larch	83	20	7.5	40	327	60	...do..	.....	125	2.50	103.75	12.22	279.54	176.57	68.39	88.4	85.3	6,066	87.17	35.8	30.52	118.1	36.92	82.8
White spruce	84	17	7.5	20	328	37	...do..	.....	125	2.50	77.85	34.90	255.40	.....	70.52	75.2	96.7	6,740	.....	22.8	22.11	103.2	22.80	97.9
White spruce and park.	85	21	7.5	20	326	41	...do..	.....	125	2.50	109.70	28.30	352.91	.....	69.59	107.3	97.9	7,277	.....	23.0	22.49	102.5	23.95	94.0
Hemlock	86	20	7.5	20	328	40	...do..	60–120	125	2.50	104.21	43.04	323.40	.....	70.88	94.5	90.1	6.506	.....	23.4	21.15	110.6	24.05	87.9
White spruce and bark.	87	19	7.5	21	.....	40	...do..	.....	125	2.50	107.34	26.12	319.09	.....	70.49	94.10	87.6	6.594	.....	22.5	19.60	114.6	20.07	97.6
Spruce bark	88	20	7.5	20	328	40	...do..	.....	125	2.50	57.25	9.96	132.80	72.85	62.37	49.9	87.1	5.304	62.10	19.6	17.07	114.7	24.42	69.9
White spruce	89	19.5	7.5	20.5	328	40	...do..	.....	125	[3] 2.50	121.35	27.34	346.19	.....	70.37	102.8	84.8	5.967	.....	20.1	17.02	118.2	25.18	67.8
White spruce	90	20	7.5	20	329	40	...do..	.....	125	[3] 1.80	120.47	27.88	344.69	.....	70.23	102.4	85.0	6.882	.....	23.2	19.69	118.2	22.38	87.8
Longleaf pine and spruce.	91	23	7.5	20	.....	43	...do..	.....	125	[4] 1.00 [5] .599	162.50	14.43	451.06	.....	65.24	156.8	96.4	5.380	.....	15.0	14.93	100.5	20.58	72.8
White spruce	92	20	7.5	20	331	40	...do..	.....	125	[4] 1.80 [5] .599	122.86	23.32	366.67	.....	67.99	117.3	95.7	6.848	.....	21.4	20.44	104.5	23.61	86.4
	93	20	7.5	10	327	30	...do..	.....	100	[3] 1.80	126.15	19.72	342.09	.....	70.38	101.7	81.8	6.730	.....	22.3	18.25	122.1	24.32	75.2
	94	20	7.5	20	331	40	...do..	.....	125	[4] 1.80 [5] 1.20	118.60	21.38	350.42	.....	67.39	115.5	92.5	7.142	.....	21.0	19.44	107.9	25.80	75.3
	95	20	7.5	20	328	40	...do..	.....	100	[6] 1.17	127.71	22.37	374.64	.....	69.70	113.6	88.3	6.624	.....	22.1	19.59	112.8	23.58	83.3
	96	20	7.5	20	327	40	...do..	.....	125	[4] 1.60 .35	126.51	22.52	363.76	.....	68.66	114.0	90.25	7.031	.....	22.6	20.34	110.9	20.40	99.9
	97	20	7.5	20	332	40	...do..	.....	125	[4] 1.90 [7] 2.38	131.85	19.29	386.81	.....	67.59	125.03	93.25	7.308	.....	23.0	21.45	107.0	24.65	87.2
Digested spruce	98	19	7.5	20	333	39	...do..	.....	125	[4] 2.5	66.82	40.08	257.91	.....	73.08	69.40	104.0	1.668	.....	6.3	6.56	96.0	.....	.....
Sugar pine	99	20	7.5	20	333	40	...do..	.....	150	[4] 2.5	109.10	58.25	338.17	.....	73.14	90.80	83.22	5.819	.....	21.7	18.03	120.0	20.80	87.5
	100	20	7.5	20	331	40	...do..	.....	125	[4] 1.8 [8] .1	136.30	19.75	381.82	.....	69.55	116.2	85.30	7.540	.....	24.8	21.12	117.4	23.43	90.0
	101	20	7.5	20	330	40	...do..	.....	125	[4] .9 [8] .9	131.12	16.00	372.29	.....	65.70	127.29	97.10	7.340	.....	21.5	20.86	103.0	21.81	95.8
	102	20	7.5	20	328	40	...do..	.....	125	[8] 1.8	134.14	15.10	381.58	.....	66.85	126.51	94.20	6.808	.....	20.6	19.37	106.3	24.80	78.2
	103	21	7.5	20	326	41	...do..	.....	125	[4] 2.5	107.13	53.15	265.40	.....	60.87	104.0	97.2	7.632	.....	21.5	20.84	103.0	26.52	78.8
White spruce	104	20	7.5	20	328	40	...do..	.....	125	[4] 1.8 [9] .1	134.55	13.86	381.41	.....	68.46	120.2	89.25	7.560	.....	24.0	21.42	112.0	23.21	92.3
	105	19	7.5	20	330	39	...do..	.....	125	[4] 2.0	151.11	11.94	424.21	.....	68.20	134.8	89.3	7.672	.....	25.1	21.52	112.0	24.52	87.8
	106	18	7.5	20	328	38	...do..	.....	125	[4] 2.0	134.55	15.35	385.40	.....	66.20	130.1	96.8	7.322	.....	21.6	20.92	103.5	25.78	81.3
	107	20	7.5	20	331	40	...do..	.....	125	(10)	145.1	13.60	411.85	.....	66.70	137.3	94.6	6.336	.....	18.9	17.93	105.7	21.82	82.4
	108	20	7.5	20	324	40	...do..	.....	125	[4] .9 [11] .9	146.3	13.51	411.81	.....	64.69	145.2	98.0	6.939	.....	19.9	19.47	102.0	26.92	72.5

[2] Cook No. 67 was not uniformly cooked; cook No. 68 was made as a check.
[3] HCL.
[4] H_2SO_4.
[5] NaCl.
[6] $KClO_3+H_2SO_4$.
[7] $KClO_3$.
[8] H_3PO_4.
[9] $FeSO_4$.
[10] Niter cake=1.8 H_2SO_4.
[11] Niter cake.

LIST OF PATENTS.

Patent.	No.	Date.	Name.	Title.
United States.	101783	Apr. 12, 1870	Sten Sternberg	Improvement in the manufacture of sugar and alcohol from lichens.
Do	244902	July 26, 1881	S. H. Johnson	Production of saccharine substances.
Do	278562	May 29, 1883	A. C. Landry, Chas. Lauga.	Method of and apparatus for converting amylaceous and ligneous substances into grape sugar.
Do	607091	July 12, 1898	E. Simonsen	Treatment of materials containing cellulose.
Do	647805	Apr. 17, 1900	A. Classen	Process of converting wood into fermentable sugars.
Do	654518	July 24, 1900	do	Process of converting cellulose into sugar.
Do	695795	Mar. 18, 1902	do	Do.
Do	696800	Apr. 1, 1902	do	Do.
Do	700616	May 20, 1902	do	Process of converting cellulose into fermentable sugar.
Do	[1] 12108 [1] 707903	May 5, 1903 Aug. 26, 1902	do	Process of converting wood into sugar.
Do	[1] 12069 [1] 654518	Dec. 30, 1902 July 24, 1900	do	Process of converting cellulose into sugar.
Do	707903	Aug. 26, 1902	do	Process of converting wood into sugar.
Do	745675	Dec. 1, 1903	H. R. Zeutzen, L. Roth.	Process of making glucose.
Do	755390	Mar. 22, 1904	G. Reynaud	Manufacture of dextrine.
Do	761542	May 31, 1904	do	Process of making achro-o-dextrose.
Do	763472	June 22, 1904	M. F. Ewen, G. H. Tomlinson.	Process of converting wood cellulose.
Do	807250	Dec. 12, 1905	C. F. Gross	Manufacture of sugar from cellulose.
Do	825808	July 10, 1906	A. Classen	Process of converting cellulose of wood into fermentable sugars.
Do	930274	Aug. 3, 1909	H. W. Doughty, F. E. Wetees.	Method of treating wood during distillation.
Do	938308	Oct. 26, 1909	M. F. Ewen, G. H. Tomlinson.	Process of producing fermentable sugar from ligno-cellulose.
Do	970029	Sept. 13, 1910	Gista Ekström	Process of making grape sugar.
Do	985725	Feb. 28, 1911	W. P. Cohoe	Method of making a fermentable product from cellulosic and ligneous materials.
Do	985726	do	do	Method of making a glucoselike product from cellulosic and ligneous materials.
Do	1031088	July 2, 1902	A. F. Richter	Combination-digester.
Do	1032392	July 16, 1912	M. F. Ewen, G. H. Tomlinson.	Process of producing fermentable sugar from ligno-cellulose.
Do	1032440	do	G. H. Tomlinson	Do.
Do	1032441	do	do	Process of feeding materials to digesters.
Do	1032442	do	do	Do.
Do	1032443	do	do	Process of treating ligno-cellulose for recovering turpentine and sugar.
Do	1032444	do	do	Apparatus for treating ligno-cellulose for recovering turpentine and sugar.
Do	1032445	do	do	Apparatus for feeding materials to digester.
Do	1032446	do	do	Apparatus for treating comminated ligno-cellulose.
Do	1032447	do	do	Process of treating comminated ligno-cellulose.
Do	1032448	do	do	Process of producing fermentable sugars from cellulosic materials.
Do	1032449	do	do	Apparatus for treating ligno-cellulose.
Do	1032450	do	do	Process of producing fermentable sugars.
Do	1033064		F. E. Gallagher, H. S. Mork.	Process of producing fermentable sugars from ligno-cellulose.
Do	1037185	Aug. 27, 1912	do	Process of producing fermentable sugars.
Do	1042332	Oct. 22, 1912	G. Ekström	Method of manufacturing alcohol from sulphite liquor.
Do	1046160	Dec. 3, 1912	do	Manufacture of ethyl alcohol by fermenting sulphite liquor.
Do	1050723	Jan. 14, 1913	do	Manufacturing alcohol from sulphite liquor.
Do	1056161	Mar. 18, 1913	F. E. Gallagher	Process of producing fermentable sugars.
Do	1056162	do	F. E. Gallagher, H. S. Mork.	Process of producing sugars from cellulose.
Do	1056163	do	F. E. Gallagher	Process of producing fermentable sugars.
Do	1087356	Feb. 17, 1914	G. Ekström	Method of removing organic constiuents from residues obtained in producing alcohol from waste sulphite cellulose lyes of similar liquid.
Do	1087743	do	do	Method of producing cellulose.
Do	1087744	do	do	Converting of cellulose into fermentable sugar.

[1] Reissue.

List of patents—Continued.

Patent.	No.	Date.	Name.	Title.
United States.	1091327	Mar. 24, 1914	F. E. Gallagher	Process of producing fermentable sugars.
Do	1096030	May 12, 1914	F. E. Gallagher, H. S. Mork.	Do.
Do	1101061	June 23, 1914	A. Classen	Conversion of wood or other cellulose material into glucose and other soluble and insoluble carbohydrates.
German	29025	Jan. 22, 1884	P. Fliessbach	Verfahren der Behandlung von Pülpe aus der Kartoffelstärkefabrikation zur Erzeugung von Dextrin, Traubenzucker, Syrup u. s. w.
Do	32388	Dec. 3, 1884	L. Aubert, V. Giraud	Von der Unwandlung von Stärke und Cellulose in Rohrzucker (Saccharose) unter Anwendlung von Elektrizität.
Do	66158	Nov. 15, 1891	C. Kappesser	Ver. zur Herstellung von zuckerhaltigen Flüssigkeiten und Alcohol aus Torf.
Do	77158	Aug. 22, 1891	C. Pieper	V. zur Darstellung von Traubenzucker u. Zuckersyrup unmittelbar aus Kartoffelreibse Kartoffelpülpe, Schlammstärke u. s. w.
Do	92079	Dec. 2, 1894	E. Simonsen	V. zur schnellen Umwandlung von Holz, Sagespähnen u. dgl. in Gahrfähige Products mit Hülfe von Säuren.
Do	111868	July 15, 1899	A. Classen	Verf. zur Ueberführung der Holzfaser in Dextrose.
Do	118540	Sept. 24, 1899	do	V. zur Ueberführung von Holz u. and. cellulosehaltigem Material in Zucker Dextrose.
Do	118541	Nov. 21, 1899	do	V. zur Ueberführung von Stärke, Stärke haltigen u. s. ähnlichen Material in Zucker Dextrose.
Do	118542	May 12, 1900	do	V. zur Uberf. von Holz u. s. w. in Zucker unter Aufschliessen mit Chlor.
Do	118543	May 1, 1900	do	Neuerung in Verf. zur Ueberf. von Holz u. s. w. in Zucker.
Do	118544	May 12, 1900	do	Neuerung in V. zur Ueberf. von Holz u. s. w. in Zucker.
Do	121869	Oct. 17, 1900	do	Verf. zur Ueberführung von Holzfaser in Dextrose.
Do	130980	June 9, 1901	do	Verf. zum Verzuckern von Holz durch schweflige Säure in Druckgefassen.
Do	123911	Oct. 17, 1900	do	Addition to Patent No. 121,869. Title same as 121,869. Specifies heating to 125°-135° C.
Do	147844a	May 26, 1901	R. Gentzen, L. Roth	Verf. zur Gewung von für die Spiritusfabrikation verwendbaren Maiselen aus Pflanzen und pflanzlichen Abfallstoffen.
Do	193112	Jan. 17, 1906	G. Ekström	Verf. zur Herstellung von Traubenzucker oder Ethyl Alcohol aus Zellulose haltigen Stoffen.
Do	207354	Aug. 8, 1907	do	Addition to Patent No. 193,112.
Do	318203	Oct. 9, 1902	Reynaud	Pour nouveau procédé de transformation de la cellulose des végétaux en glucose et ses derives.
English	358696	Mar. 3, 1906		Compagnie Industrielle des Alcools de L'Ardèche, France. Rotary apparatus for saccharifying wood.
Do	380358	Dec. 6, 1907	Ekström, G	Procédé pour la fabrication du sucre de raisin ou éventuellement de l'alcool ethylenigne, au moyen de matières contenant de la cellulose.
Do	358696	do		Compagnie Industrielle des Alcools de l'Ardèche. Rotary apparatus for saccharifying wood.
Do	393336	do	Bouchand Praceign	See Zeit. für Angw. Chemie, 1910, *23*, page 916.
French	405187	Dec. 22, 1909	J. J. D'Orlowski	Procédé pour la fabrication de l'alcool avec de la sciure de bois de la cellulose, de l'amidon et des matières amylacées.
Do	12872	1849	C. Montgomery	Brewing, distilling, and rectifying.
Do	34	1854	M. Poole	Processes for the manufacture of dextrine and glucose for distillation and application of the products thereof.
Do	1246	1854	H. Bordier	Manufacture of ligneous alcohol.
Do	2281	1854	R. H. Brooman	Obtaining alcohol from organic substances.
Do	2433	1856	T. F. Henley	Producing alcohol and food for cattle.
Do	1283	June 7, 1858	J. B. A. Lombard, X. T. Esquiron.	Obtaining saccharine substances from cereal and vegetable matters, etc.

List of patents—Continued.

Patent.	No.	Date.	Name.	Title.
English	268	Jan. 21, 1880	A. M. Clark	Obtaining glucose and alcohol from ligneous materials.
Do	4334	Oct. 23, 1880	S. H. Johnson	Production of saccharine substances.
Do	4514	Nov. 4, 1880	Wm. F. Nast	Manufacture of sugar, etc., from cellulose or ligneous materials.
Do	11407	Aug. 18, 1884	H. H. Lake	Improvements relating to apparatus for treating ligneous substances for the production of glucose.
Do	11557	Aug. 22, 1884	A. M. Clark	Improved apparatus for use in treating wood and other ligneous matters by means of hydrochloric acid gas, in order to obtain glucose therefrom.
Do	1767	Feb. 9, 1885	Adolph Behr	Improved apparatus and process for obtaining cellulose and glucose from wood and other vegetable matter.
Do	10164	Aug. 9, 1886	H. J. Hadden	Improvement in the treatment of Jerusalem artichoke to prepare it for use in distilling in the manufacture of glucose and similar industries.
Do	13653	Aug. 29, 1889	Paul Marix	A new or improved process for the purification of mineral oils and for producing alcohol.
Do	21059	Dec. 2, 1891	C. Kleyer, C. Kappesser	Improvements in the treatment of peat for the production of cellulose sugar and alcohol.
Do	13492	July 12, 1894	R. Zdarek	Improvements in the manufacture of alcohol.
Do	10762	May 30, 1895	E. Simonsen	An improved process for the treatment of materials containing cellulose for the production of spirits.
Do	21314	Nov. 11, 1895	A. L. Tedesco	Process for manufacturing pure dextrose.
Do	21878	Sept. 24, 1897	R. Zdarek	Improvements in the manufacture of ethyl alcohol.
Do	24013	Nov. 15, 1898	N. Basset	Method of treating cellulose.
Do	1035	June 16, 1899	C. F. Cross, J. S. Remington.	Improvement in the production of starch and saccharine matters.
Do	12 241	June 12, 1899	Paul Magnier, P. A. Brangier.	Improved process for convering wood, wood shavings, woody fiber, sawdust, and other substances into dextrine, glucose, and alcohol.
Do	258	Jan. 4, 1900	Alex Classen	Process for converting cellulose and starch into fermentable sugar.
Do	259	do	do	Process of converting wood into fermentable sugar.
Do	4199	Feb. 27, 1901	do	Improved process for converting cellulose into sugar (dextrose).
Do	12588	June 20, 1901	do	Process for converting wood and other cellulose materials into sugar.
Do	8545	Apr. 13, 1904	C. F. Cross	Treatment of cottonseed hulls to obtain useful products therefrom.
Do	11113	May 13, 1904	W. H. Wheatley	Method of preparing must for the manufacture of spirits of wine, the feeding of cattle, and the manufacture of dextrose.
Do	16262	July 22, 1904	Arno Börner	A new or improved process for the manufacture of starchlike or Amyloidlike substances and sugar.
Do	22709	Nov. 6, 1905	Alex Classen	Process for facilitating the fermentation of sugar solutions obtained from wood that contains tannin.
Do	16510	July 21, 1906	B. E. E. Newlands	Improvements in connection with the production of alcohol from wood.
Do	5128	Mar. 2, 1907	C. S. Lake	Improvements in and relating to the treatment of peat for the production of alcoholic and other products.
Do	24503	Nov. 5, 1907	Boren Hafner, Frank Krist.	Improved manufacture of fermentable sugar from materials containing starch or cellulose.
Do	18341	Aug. 13, 1907	G. Ekström	An improved process for making grape sugar (glucose) and ethyl alcohol from materials containing cellulose.
Do	5128	Mar. 2, 1907	H. H. Lake	Improvements in and relating to the treatment of peat for the production of alcoholic and other products.
Do	26619	Dec. 8, 1908		Compagnie Industrielle des Alcools de L'Ardèche. Improvements in or relating to apparatus for converting wood into fermentable sugars and other products.

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